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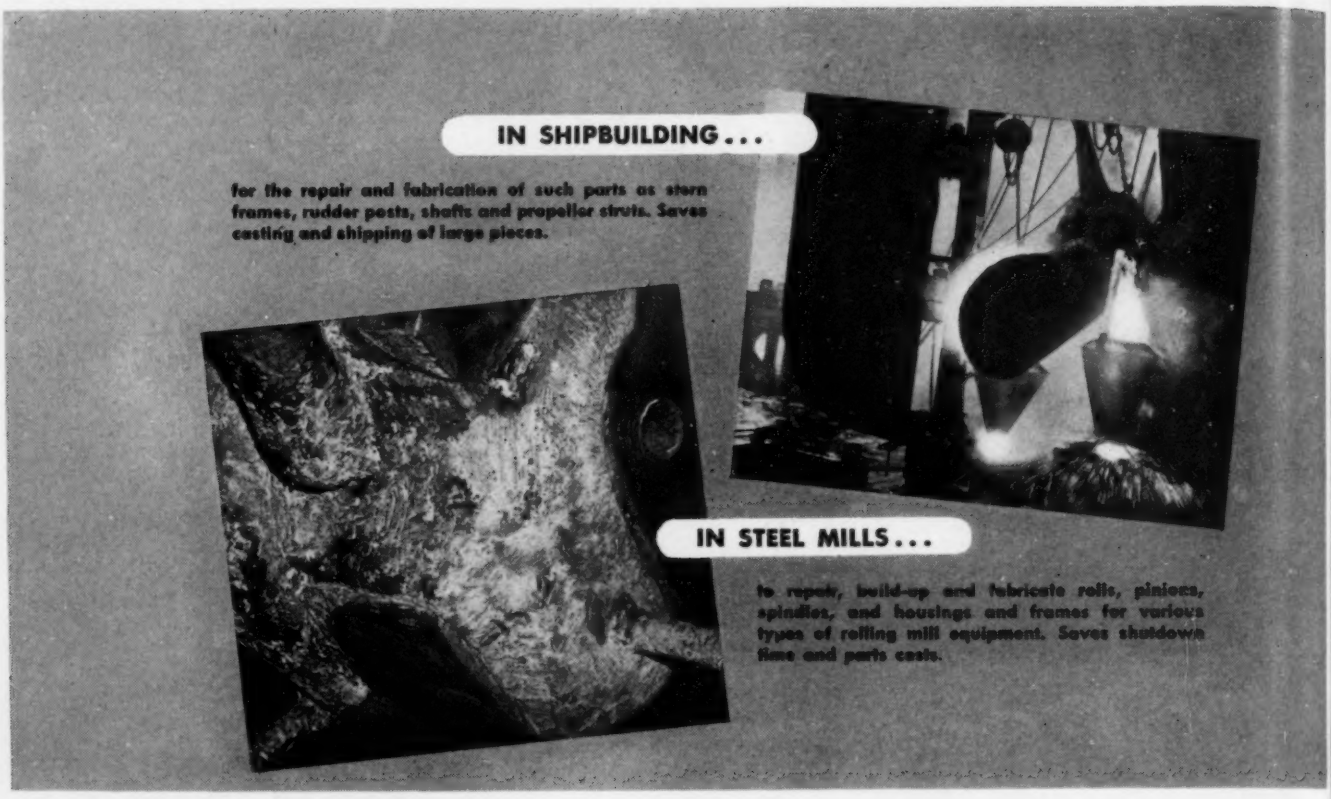
The WELDING Journal

The Journal of The American Welding Society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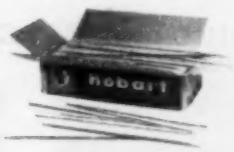

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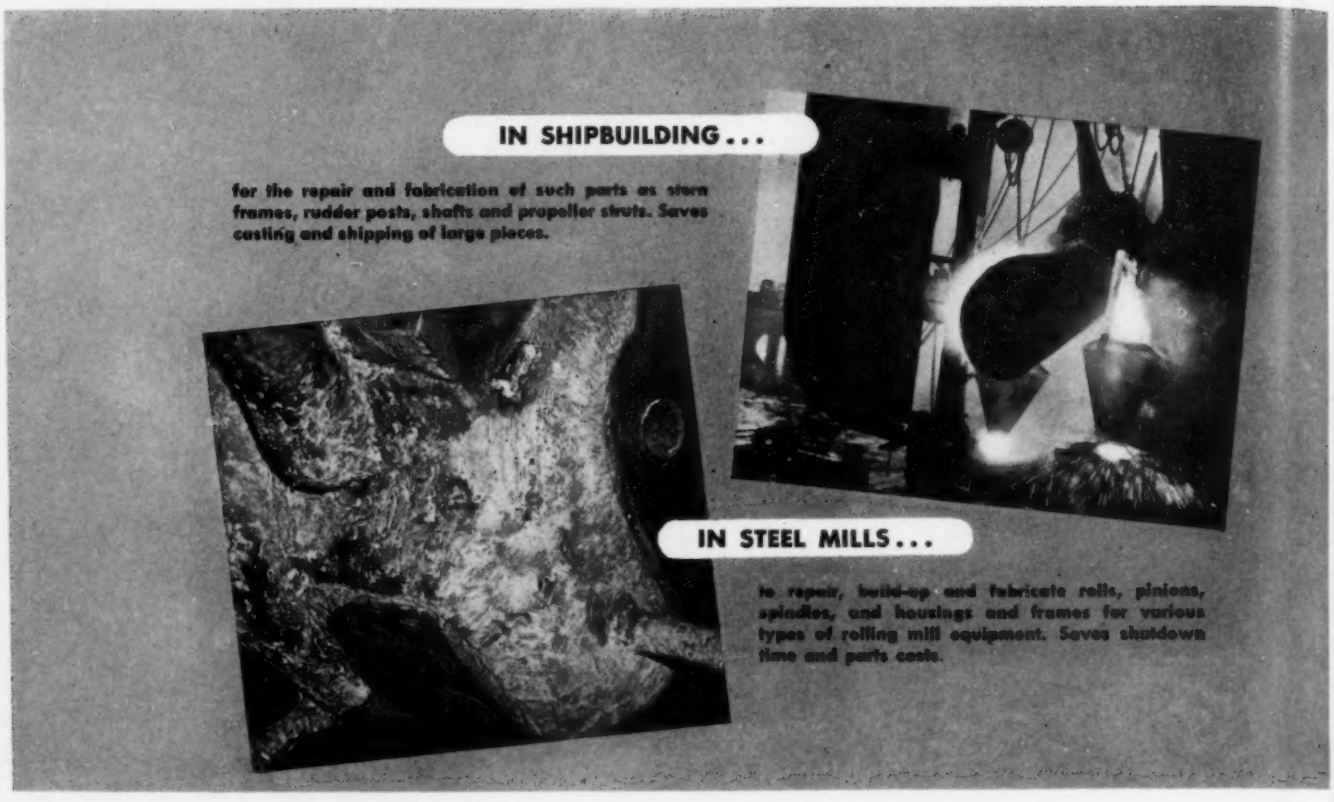
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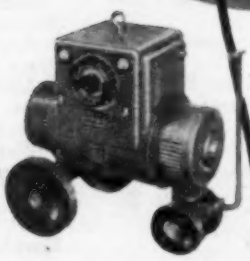

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The Journal of the American Welding Society

Published for the Advancement of the Science and Art of Welding

W. SPRARAGEN, Editor

MARCH 1947

VOLUME 26 NUMBER 3

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CONTENTS

TECHNICAL PAPERS, ITEMS AND REPORTS

Powder-Cutting and Scarfing of Oxidation-Resistant Materials, by D. H. Fleming, Jr. 201
Development and Applications of Lime-Ferritic Electrodes, by D. L. Mathias and A. P. Bunk..... 209
Spot Welding Under Water, by Charles L. Coomer..... 217
Building Code Requirements for Welding Structural Steel, by Simon A. Greenberg..... 219
Radiography and the Fatigue Strength of Spot Welds in Aluminum Alloys, by R. C. McMaster and H. J. Grover..... 223
Choice of Cable and Transformer Size for Portable Spot Welders, by Myron Zucker..... 233
Discussion by A. C. Johnson..... 238
The Evolution of Diesel Engine Block Weldment Design and Fabrication, by James W. Owens..... 240

SOCIETY AND RELATED ACTIVITIES

Minutes of the Meeting of Executive Committee, A.W.S..... 248
Stress and Strain in Plastic Flow.... 250
1947 A.W.S. Directory..... 252
Resistance Welding Research..... 252
INDEX TO ADVERTISERS..... 252
Fracture of Metals..... 254
The A. F. Davis Undergraduate Welding Award..... 254
Flash Welding Book..... 254
Arc Welding Inspection Handbook.. 254
Adams Lecture Series..... 254
Engineering Foundation Asks Bequests and Gifts to Aid Research Projects in Engineering..... 254
Ostrom Expands..... 256
A.S.M.E. Boiler Construction Code Sec. VIII Redrafted..... 258
Progressive Membership Reaches 50 258
223-Ton Steel Vessel for Testing High-Pressure Underwater Equipment.. 258
N. J. Weiss Associates..... 260
Sustaining Company..... 260
Stainless-Clad Steel..... 260
Fabricating Aluminum..... 262
American Standards..... 262
Wrought Iron Storage Tanks..... 262
Stress Analysis Meeting..... 262
Stud Welding Data Book and Catalog Announced..... 264
Resistance Welding Manual—Revised Edition..... 264
Welding Flux..... 264
Free Pamphlet on Storage of Micro-Films, Sheet Films and Prints Offered by Kodak..... 264
Welding and Cutting Catalog..... 264
Accident Prevention..... 264
Metallurgical Engineers, Inc..... 266
O. B. J. Fraser Appointed Assistant Manager of INCO Development and Research Division..... 266
Wallner Welding Supply Company Appointed Lincoln Dealer..... 266
Pryor Elected President of Magnolia Airco Gas Products Co..... 268
P. M. Hall Accepts Appointment as Technical Executive of Resistance Welder Manufacturers' Association 268
Resistance Welder Manufacturers' Association Announces New Officers 268
Steel Stack..... 270
Employment Service Bulletin... 270
Progress of Welding in Great Britan 270
Templeton, Kenly & Co. Bulletin.... 270
Book Catalogue..... 270
New Products..... 274
Abstracts of Current Welding Patents, Prepared by V. L. Oldham. 280
Section Activities..... 282
List of New Members..... 285
Members Reclassified..... 292

WELDING RESEARCH SUPPLEMENT

Static and Fatigue Tests of Arc-Welded Aluminum Alloy 61-S-T Plate, by E. C. Hartmann, Marshall Holt and A. N. Zamboky..... 129-s
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The Journal of
The American Welding Society
VOLUME 26 · NUMBER 3 · MARCH 1947

Powder-Cutting and Scarfing of Oxidation-Resistant Materials*

By D. H. Fleming, Jr.†

IN THE period from World War I to World War II, oxyacetylene cutting, as applied to carbon steels, made steady progress and has now become an indispensable tool in industry for the production and fabrication of these materials. The process is used in the steel mill for the conditioning of carbon steels and low-alloy materials; for preliminary sizing of ingots, billets and slabs, for scrapping operations; and for a multitude of other uses. In the foundry, it has been widely used in the removal of risers from castings that would otherwise have to be laboriously sawed; in the washing off of riser pads; and in the gouging out of defects prior to subsequent rewelding. In the steel-fabrication industry, it is indispensable in the cutting of plates to size, shape-cutting, preparing plate edges for welding, in gouging weld deposits for rewelding, and in other applications too numerous to mention.

Stainless Steels Difficult to Cut

During this same period, the manufacture and use of stainless steels have expanded greatly. However, the nature of these steels prevents application of the techniques and economies of oxyacetylene cutting to the manufacture and fabrication of this material. The alloying elements, chromium and nickel, which impart the desirable properties to stainless steels, have made these steels difficult or impossible to process by normal oxyacetylene cutting. Of the two, the chromium represents the greatest problem, for when any oxyacetylene cutting is applied to stainless steels, the chromium, which has a high affinity for oxygen at elevated temperatures, immediately forms the highly refractory chromium oxide on the faces of the kerf and prevents further oxidation. The nickel does not appear to present so much of a problem inasmuch as a refractory oxide of this material is not formed.

A number of means have been used in the past to get around the refractory effect of chromium oxide. The most commonly used process involves the use of an oscillatory motion of an ordinary hand-cutting blowpipe. An extremely heavy preheat and oversized nozzles are used and the special manipulation of the blowpipe is shown in Fig. 1. The overall economy of the process is not very good, for the cutting is quite ragged and the speeds are slow. Figure 2 shows a comparison of hand-cutting on 4-in. square billets by the oscillation method and by powder. Using the same size nozzle and operating conditions, the time required by the oscillation method was three and a half times that required by the powder cutting method. A second method is to hand-feed an iron rod or wire into the reaction zone. The rod is semi-atomized when it comes in contact with the cutting-oxygen stream and provides molten droplets of

* Presented at the Twenty-Seventh Annual Meeting, A.W.S., Atlantic City, N.J., week of Nov. 17, 1946.
† Development Engineer, The Linde Air Products Co.

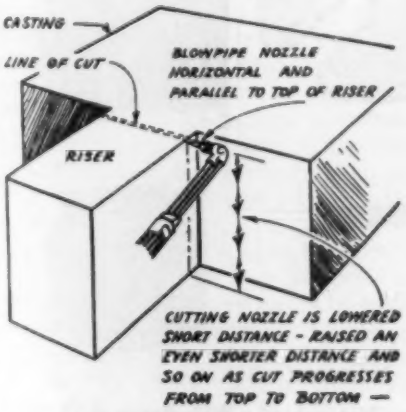
CASTING
LINE OF CUT
BLOWPIPE NOZZLE HORIZONTAL AND PARALLEL TO TOP OF RISER
RISER
CUTTING NOZZLE IS LOWERED SHORT DISTANCE - RAISED AN EVEN SHORTER DISTANCE AND SO ON AS CUT PROGRESSES FROM TOP TO BOTTOM —

Fig. 1—This Sketch Indicates the Oscillation Technique Required for Cutting Stainless Steel Without Powder

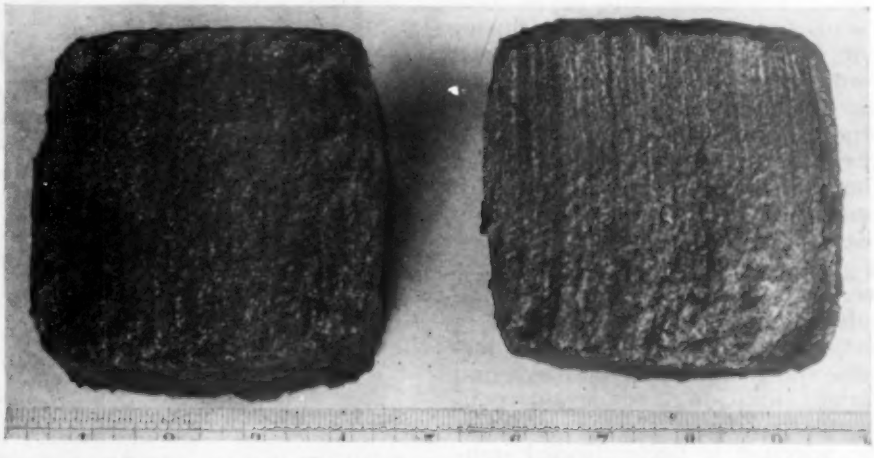

Fig. 2—The Cut on the 4 by 4-In. Billet at the Left Was Made by the Oscillation Method, While the One on the Right Was Made with Powder. Three and a Half Times as Much Total Cutting Time Was Required by the Former, and the Metal Loss in the Kerf Was Twice as Great as with Powder

Fig. 3—Powder-Cutting Data Clean 18-8 Stainless Steel

Thickness, In.	Nozzle Size	Cutting Oxygen, Lb. per Sq. In.	Powder Consumption, Lb. per Hr.	Cutting Speed, In. per Min.
1/4	4	50	15	24
1/2	6	50	18	20
1	6	50	18	15
2	8	50	18	11
4	10	50	18	7
6	12	50	22	5
8	14	65	24	4
10	16	65	24	4
12	20	75	30	4
14	20	75	45	3
16	24	75	45	3
18	24	75	45	2
20	24	75	45	2

iron oxide to act as a fluxing agent in the cutting. The third method is to use a plain carbon steel waster plate on top of the stainless steel. The products of oxidation produced in the waster plate are washed on to the stainless steel and provide the necessary heating and fluxing action. The fourth method is the use of a carbon or metallic electrode to melt away the stainless steel. This last method is extremely slow, particularly on large sections, but requires little skill inasmuch as it is simply a melting action from the heat of the arc. At best, these techniques give only a severing cut that is suitable for only the roughest work.

Because of the limitations of these severing methods, mechanical means have been used almost exclusively for the conditioning and cutting of stainless materials until the advent of the powder-scarfing and cutting process. Now, at a considerably faster pace, powder-scarfing is doing the job of conditioning that could previously be handled only by grinding or chipping. The companion process of powder-cutting is sizing or shaping the stainless material from the time it is stripped from the ingot mold until it becomes a finished article in the fabricating shop. This short-circuits the previous mechanical methods of nibbling, multiple-drilling, cold sawing or other relatively slow machining operations.

The Powder-Scarfing Process

To provide the continuous progressive application of the cutting or scarfing process to these materials and provide a high-quality cut surface, it was necessary to devise some means for either melting or fluxing out the chromium oxide that was formed. Years of research and development have been involved in the study of materials to give the desired chemical action and concurrently in the construction of apparatus to dispense the powdered material and combat the abrasive effects of the powder. A great variety of powdered materials have been tested, ranging from individual metallic powders, mixtures of metallic powders, mixtures of metallic and non-metallic powders, and various individual or mixed non-metallic powders. The net result was the selection of finely divided iron-rich powder as the additive material because it most satisfactorily met the following requirements:

1. Non-hygroscopic material
2. Liberation of intense heat during combustion
3. Products of combustion provide fluxing action
4. Products of combustion non-irritating and non-toxic
5. Good process economy

In cutting operations this powder is usually blown into the oxygen stream from outside of the nozzle preheat flame, while in scarfing, the powder is drawn into the oxygen stream within the nozzle.

In both cases, the powder is heated to the ignition temperature by the oxyacetylene preheat flame similar in gas flow to carbon-steel preheat requirements, at which time it burns in the oxygen stream to create an extremely high-temperature reaction. The extreme heat of this reaction makes it possible to start cutting or scarfing without pausing for any preheat period. As soon as the cut progresses into the material, the refractory oxides are continuously removed by a combination melting and fluxing action. The powder that is used and the resulting products of combustion that are present in a heavy smoke cloud are both non-toxic. However, for most applications it is desirable to remove the smoke because of its nuisance characteristics.

Operating Requirements and Speeds

The use of iron-rich powder permits both scarfing and cutting operations. Hand-scarfing operations on stainless steel are carried out at a speed approximately one-fourth to one-third the speed used on carbon steel, with equivalent oxygen flows and the added factor of powder. The cutting of all types of stainless steel can be accomplished at cutting speeds comparable to equivalent thicknesses of carbon steel, but it is generally necessary to use a nozzle one size larger than that which would be used on carbon steel of the same thickness. Powder-flow requirements for cutting vary from 1/4 to 1/2 lb. per minute, depending upon the thickness of the material. Operating data obtained with powder hand-cutting nozzles are shown in Fig. 3, and characteristic cut sur-

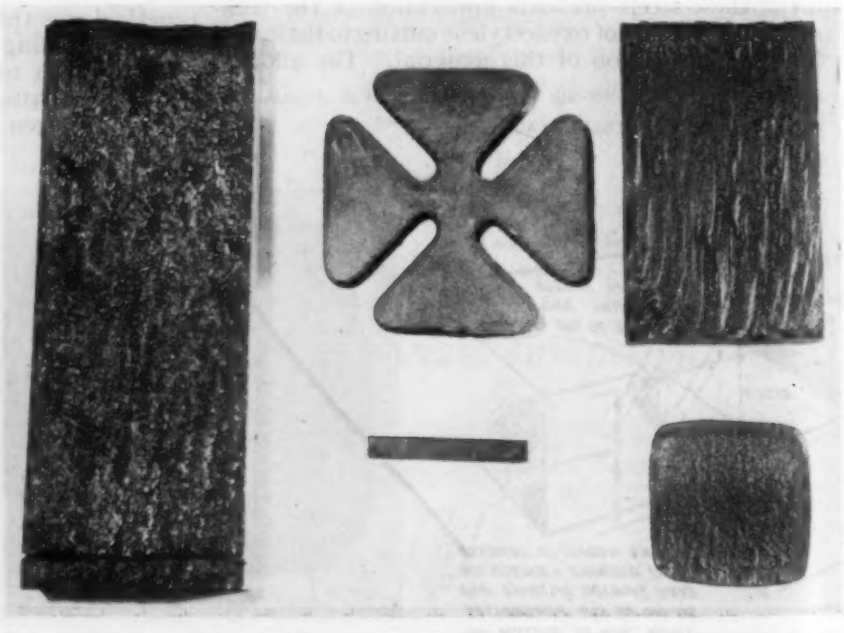

Fig. 4—Characteristic Cut Surfaces on Various Materials of a Wide Range of Thicknesses

Left 14 in. 18–8 hot top; Top center 1/2 in. 18–8 plate; Bottom center 1/2 in. 18–8 plate; Top right 8-in. cast iron; Lower right 4 x 4 in. 25–20 billet.

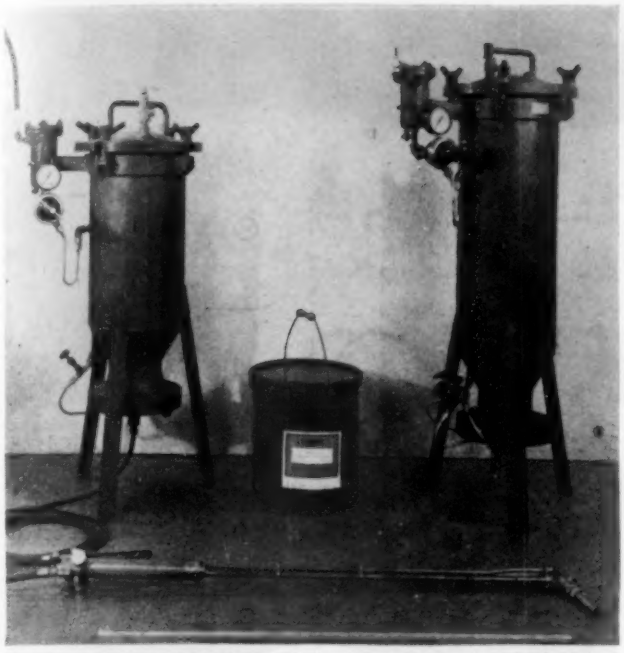

Fig. 5—Single and Triple Outlet Dispensers Used in the Powder Process Together with a 100-Lb. Drum of Powder and a 44-In. Hand Scarfing Blowpipe

For hand-scarfing, a special 44-in. long powder blowpipe is used. In addition to the usual two-hose oxyacetylene hookup, a third hose carrying the powder is led to the blowpipe from the powder dispenser. Single and triple outlet dispensers together with a 44-in. scarfing blowpipe and a 100-lb. drum of powder are shown in Fig. 5. The powder passages are an integral part of the blowpipe construction. The same general design is used for the hand-cutting blowpipe, which is 28 inches long. Special powder-scarfing and powder-cutting nozzles are used in conjunction with these hand-operated blowpipes. The valve lever that ordinarily actuates the cutting oxygen is also used to turn on the powder on these particular blowpipes. The valves are so arranged that the powder comes on slightly before the cutting oxygen, to further insure a flying start.

A series of four machine cutting attachments have been made to fit blowpipes from the smallest to the largest size, and are capable of cutting stainless steel ranging from $^1/_8$ inch to 26 inches in thickness. These attachments are designed to be added to standard blowpipes and standard cutting nozzles. Thus a user of standard oxyacetylene equipment can cut stainless steel by the addition of a powder-cutting attachment and a powder dispenser. Figures 6 and 7 show overall and nozzle-end views of a machine-cutting powder attachment as

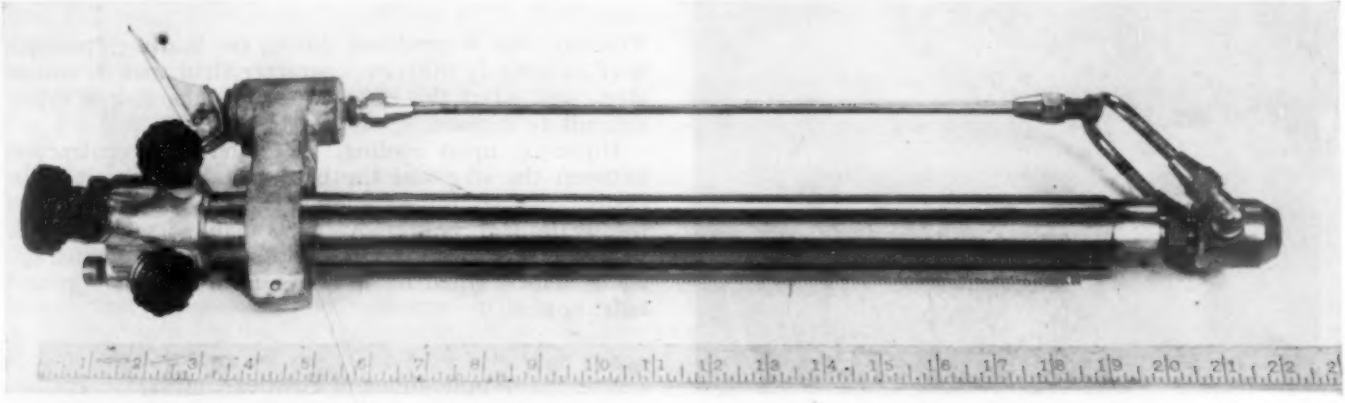

Fig. 6—A Machine-Cutting Attachment Mounted on a Standard Machine-Cutting Blowpipe

faces are shown in Fig. 4. The quality of the resulting cut surface approaches that obtained on carbon steel, although the surface is rougher, possibly because of selective oxidation of the various alloy components of the material.

An interesting feature of this process is that the high heat of combustion created by the iron powder in the cutting-oxygen stream makes flying starts possible in both scarfing and cutting of cold steel. This factor completely eliminates the preheating time common to carbon-steel cutting and particularly to the previously mentioned methods of cutting stainless steels. This factor also provides flying starts in the cutting of carbon steels on production bar-cutting machines. In this instance the powder flow is shut off immediately after the cut is started.

The apparatus required for powder-cutting or scarfing is relatively simple and inexpensive. A common piece of apparatus that is required by both cutting and scarfing is the powder dispenser. This is essentially a pressure vessel with a powder ejector built into the bottom flange. It operates entirely on a small flow of compressed air through the dispenser, the powder being picked up by the air flow through the ejector and carried through ordinary rubber hose to the blowpipe. The dispenser holds sufficient powder for at least 8 hours, continuous operation.

Fig. 7—A Nozzle-End View of the Machine-Cutting Attachment Showing the Powder Jets Surrounding a Standard Nozzle

applied to a standard blowpipe. This complete line of apparatus permits application of the powder-cutting and scarfing processes to the manufacture of stainless steel from ingot form to the final finished product, and to special high-alloy and non-ferrous materials.

Typical Scarfing Applications

In the steel mill, the process finds its principal application in the conditioning of stainless steel and in cutting of sections generally ranging from 3 to 24 or 26 inches. Large bloomed ingots, small unrolled ingots, slabs, and billets are generally the type of work handled by powder-scarfing. In the case of the bloomed ingots, these are generally covered with severe cracks and corner tears that in some cases are as deep as 2 or 3 inches. It is an extremely laborious job to remove all the cracks by grinding; however, by powder-scarfing, it is possible to condition an ingot of 12,000 lb. in a matter of 4 to 6 hours, as contrasted with a possible 48 hours or more that would be required for grinding. The small unrolled ingots generally do not have any cracks, but have a spongy

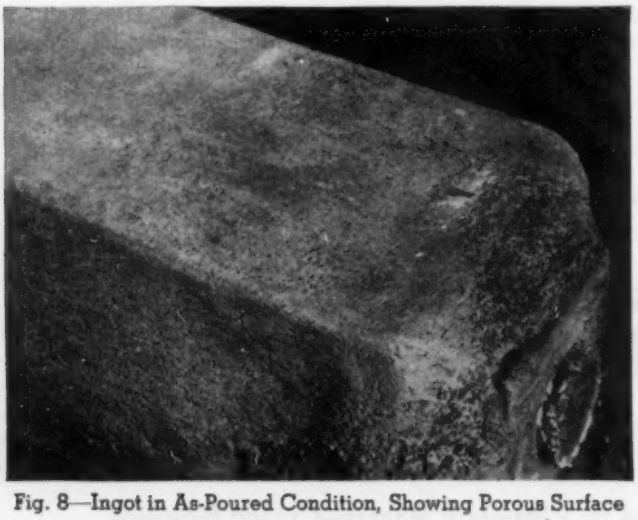

Fig. 8—Ingot in As-Poured Condition, Showing Porous Surface

surface approximately $^3/_{16}$ in. deep, as shown in Fig. 8. The spongy surface must be removed before a quality product can be rolled. This can be accomplished by completely removing the defective surface. It is possible to condition a heat of 22 to 24 1000-lb. ingots in one eight-hour turn by this method with two powder-scarfing blowpipes. An ingot in the process of being scarfed is shown in Fig. 9. (Figure 10 shows the same ingot after the scarfing has been completed.)

In the scarfing of heavy slabs and billets, the same conditions apply as in the scarfing of the small ingots or the bloomed ingots. In many cases, however, material of this type, so badly cracked that it would be economically unfeasible to condition it by grinding, can easily and quickly be reclaimed by the use of powder-scarfing because of the great speed that can be obtained. On stainless slabs and smaller cross-sectioned billets about 3 to 4 in. thick, the depth of the defects is such that grinding and scarfing are approximately equivalent on a cost basis. A higher quality job can be obtained by powder-scarfing, for it is not possible to cover up defects in the material. On the other hand, in grinding, an operator can smear over small cracks by leaning heavily on the wheel. A good powder-scarfing job will produce a surface that is nearly equivalent to that of a carbon-steel scarfed surface, as shown on 4 by 4 billets in Fig. 11.

Fig. 9—Ingot in the Process of Being Powder-Scarfed

The slag that is produced during the scarfing operation is of an entirely different character than that on carbon steel, and when the material is hot, the slag is rather difficult to remove.

However, upon cooling, the differential contraction between the slag and the base metal permits it to be easily knocked off. On exceptionally tenacious spots the scale can be removed by flame-descaling. The quality of the rolled product obtained from a scarfed billet or slab is equal to or better than that of a ground billet or slab.

Applications of Powder-Cutting

The cutting process in the steel mill has found valuable use in the removal of hot tops from large ingots or bloomed ingots. The cutting speed on heavy sections from 14 to 26 in. thick averages approximately 2 in. per min., the only variation being in the oxygen-flow requirements. It has been possible to remove the hot top from

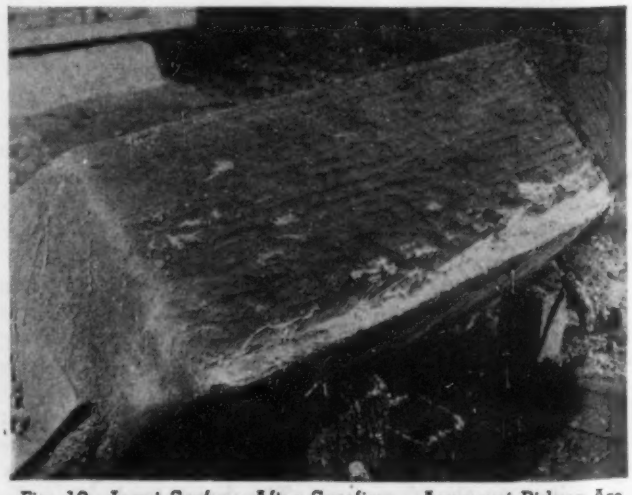

Fig. 10—Ingot Surface After Scarfing. Apparent Ridges Are Imperceptible in Rolled Product

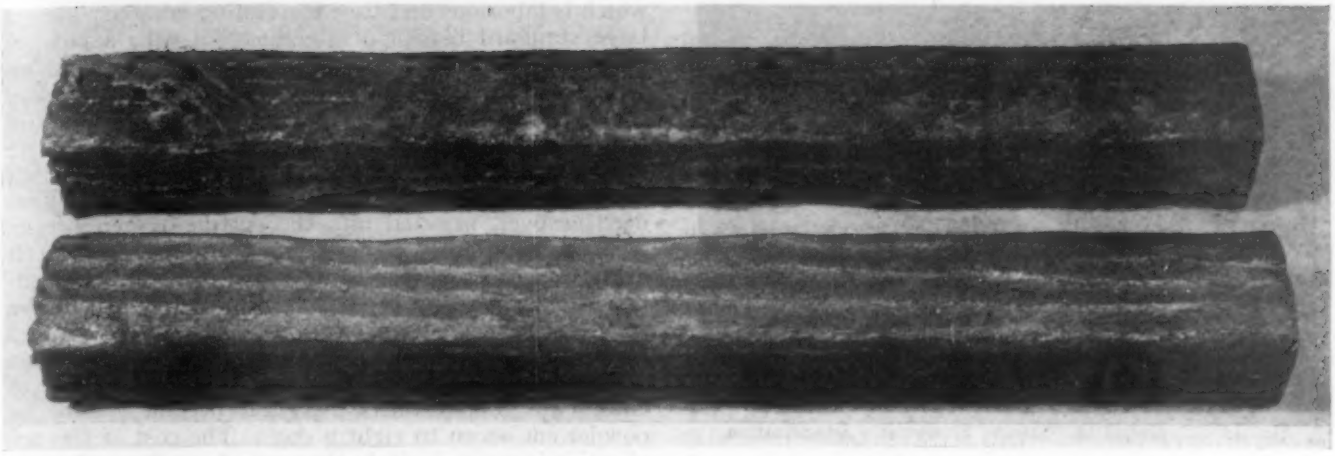

Fig. 11—High-Quality Powder-Scarfing on 4 by 4 In. Billets

ingots 18 in. thick and 56 in. wide in 28 minutes, with a high-quality edge being produced. For this class of work, nozzles providing 2000 to 2500 cu. ft. of oxygen per hr. are required, and an average of 30 to 40 lb. per hr. of powder is used. In spite of the heavy section, flying starts are obtained on this material. Prior to the inception of the powder-cutting process, these ingots were cut by the oscillation method, which required at least two hours to remove the hot top of the type mentioned. With the oscillation method, in many cases it was not possible to penetrate completely through in one pass, and it was therefore necessary to turn the ingot over and cut from the opposite side in order to complete the cut.

Slabs that are rolled from ingots often have very badly cracked edges, although the flat surfaces are in reasonably good condition. Before any re-rolling can be accomplished on these pieces, it is necessary to remove the cracks completely. In many cases the crack condition is such that the piece can be considered little more than scrap, but with the use of the powder-cutting process, it is possible to trim off the scrap edge and then subsequently cut the slab to size for rolling into final finished-plate size. The use of the powder-cutting process for removing cracked edges of slabs has resulted in a savings of thousands of dollars per week, merely by making it easier to reclaim slabs that would otherwise be considered absolute scrap. Some of this work had previously been accomplished by the use of carbon arc, but the speeds in this case were a third to a quarter of those obtained with the powder process. Slabs are also cut into smaller sections for further rolling, as shown in Figs. 12 and 13. Medium-sized billets have been cut to short lengths The billets are laid out on a bed, and the cutting proceeds from one billet to the next without stopping just as though a solid slab was being cut. For example, with a setup of this type, 115 stainless 18–8 billets, $3^1/_2$ in. by $3^1/_2$ in. were cut in half in approximately one hour.

A further use of the process in stainless steel production is the cutting to size of relatively thin plate about 1 to 2 in. thick, to be made into carbon and stainless steel sandwiches, prior to rolling into clad plate. Plate can be cut to actual customers' specification size, which is something not generally done in steel mills up to this time because of the difficulty in actually cutting the material. (See Fig. 14.) Previous work of this type required the use of saws, which was extremely slow if adequate shearing facilities were not available.

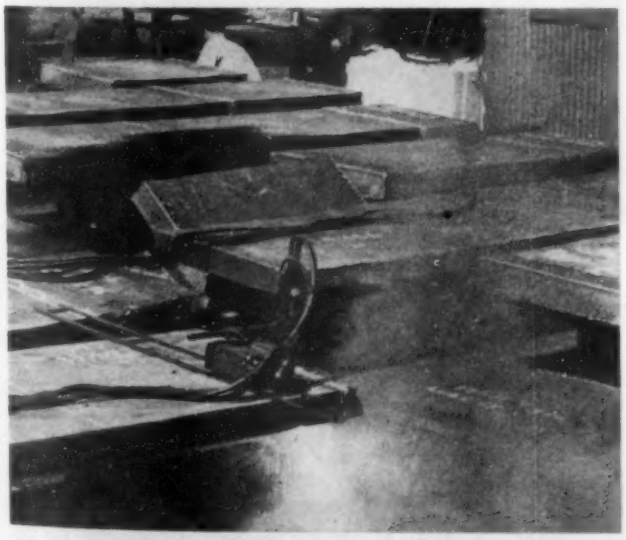

Fig. 12—Steel Mill Slab Cutting Operations on 4 to 7-In. Thick Type 18-8 Slabs. Removing Hot Top and Butt Ends from Slabs and Cutting to Smaller Patterns for Rolling to Finished Thickness

Fig. 13—Powder-Cut Slabs Ready for Rolling to Plate Sizes at Another Steel Mill

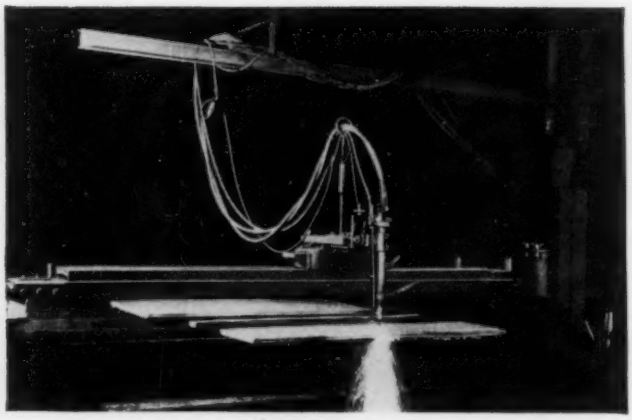

Fig. 14—Cutting 1-In. Plate to Customer's Specification

Scrapping Operations

Certain scrapping operations present rather attractive possibilities for the powder-cutting process, the first one being the reduction of thimble butts or skulls to charging-box size. Ordinarily this is done by hand-lancing, which is laborious and time-consuming job. By using a large standard blowpipe in connection with a powder-cutting attachment, it is possible to increase the scrapping speed on th se thim le butts by as much as four times. The powder is required on the carbon-steel thimble butts or skulls because of the fact that they are coated with a heavy adherent layer of furnace slag that prohibits normal cutting operations. The use of powder, however, injected into the cutting-oxygen stream, creates a sufficiently higher temperature reaction to melt away this adherent slag layer and then permits the cutting-oxygen stream to attack the underlying carbon steel in the conventional manner. Speeds of $1^1/_2$ to 2 in. per min. on butt sections up to 30 in. thick have been obtained. In one case where the practice had been to lance two thimble butts a day, it became possible to powder-cut seven to eight a day. The cost of this application is approximately the equivalent of good lancing practice. The process can also be applied to cast iron or stainless steel skulls.

The use of portable powder equipment in the rolling mill permits removal of cobbles from rolling equipment, when such mishaps occur, at a much more rapid rate than possible with the carbon arc method. A portable outfit located anywhere in the mill can be called upon for any such emergency.

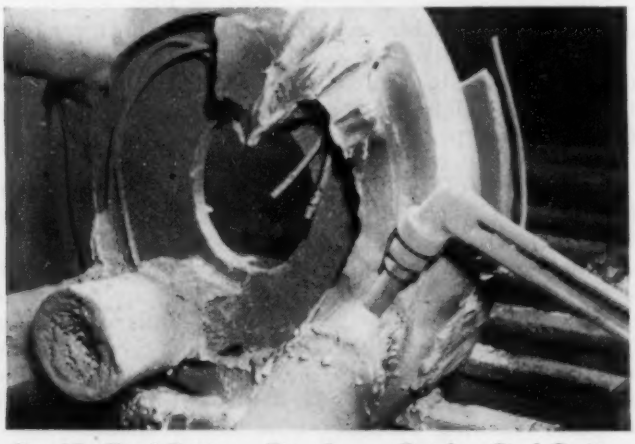

Fig. 15—Hand-Cutting a Riser from a Stainless Steel Casting

Fig. 16—Pad Surface After Removing a Riser by Powder-Cutting

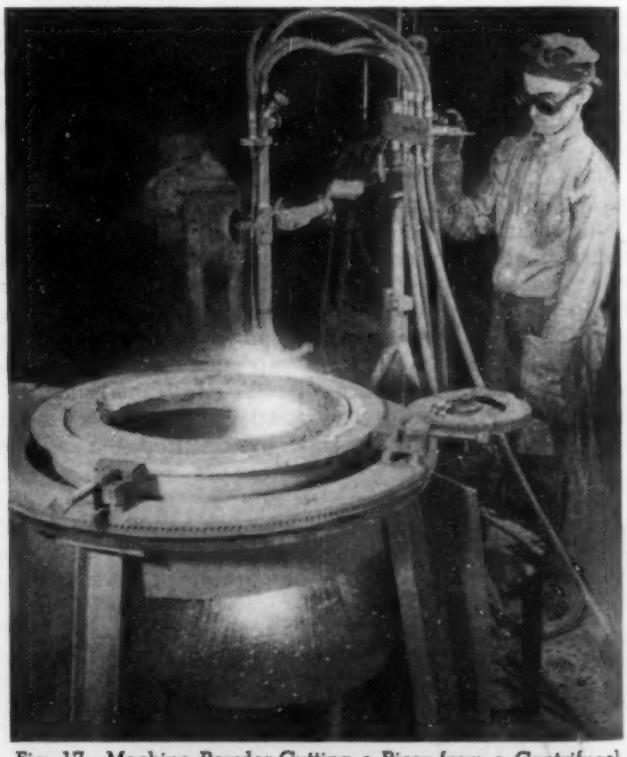

Fig. 17—Machine Powder-Cutting a Riser from a Centrifugal Stainless Steel Casting

Fig. 18—Centrifugal Casting Showing Powder-Cut Surface

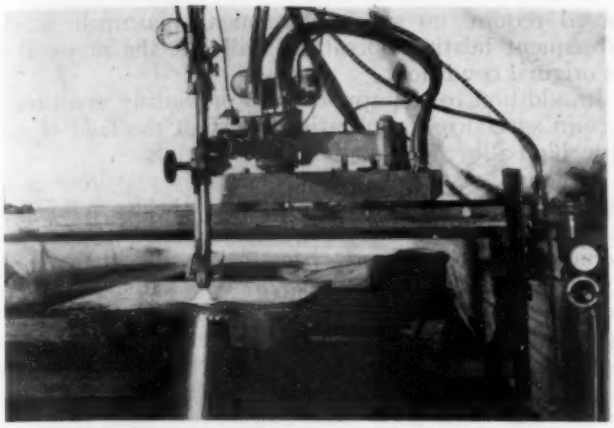

Fig. 19—Powder-Cutting Flanges in 1/2-In. Type 316 Stainless Plate, Using a Standard Type of Shape-Cutting Machine

Foundry Applications

In the stainless steel foundry, the process has found considerable application in the removal of risers that heretofore had been melted off by the carbon or metallic arc. The equipment necessary for this type of work is the powder dispenser, the hand-cutting blowpipe, and nozzles of appropriate sizes. In the removal of risers, the cutting speed obtained is nearly equivalent to that obtained in carbon-steel risers, but cutting oxygen consumptions are somewhat higher. The process has particular advantage over the carbon arc method in risers with large cross sections. A riser 6 in. in diameter can be removed by powder-cutting in a matter of 1 1/2 minutes overall time, whereas the same riser removed by carbon arc method would require about 25 to 30 minutes cutting time. The cost savings on these large risers are considerable. Figures 15 and 16 show a typical riser removal by hand-cutting in a stainless steel foundry.

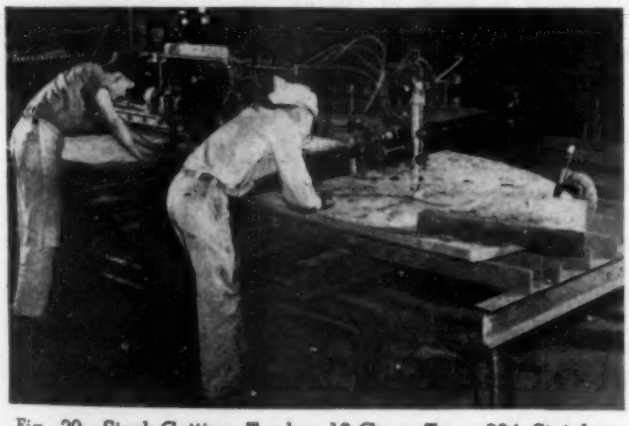

Fig. 20—Stack-Cutting Twelve 10-Gage Type 304 Stainless Steel Sheet for Chemical Equipment. Only Two C-Clamps and a Piece of Steel Slab Were Required to Hold the Stack During Cutting

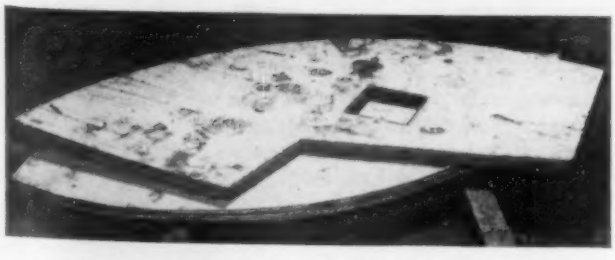

Fig. 21—The Stack Was Cut at 8 In. per Minute

When castings of one type are produced continuously, it is possible to mechanize the process with further savings, inasmuch as machine-cutting is always less expensive than hand-cutting. This has been done in several instances, particularly on centrifugal castings of rotors and the like, where there is a continuous internal ring that must be removed. An example of this is shown on Figs. 17 and 18. This ring diameter is approximately 30 in. and the material 1 1/4 in. thick. This ring was removed in 10 minutes cutting time, while the previous method used in cutting out the ring in a lathe, took more than an hour.

With a careful operator it is possible to cut closer to the casting than is possible by arc cutting, and furthermore, there is no carbon pickup on the pad surface. This means that the pad left on the casting will not contain hard spots and will be considerably easier to grind down to the casting contour. Furthermore, in order to effect carbon arc cutting, it is necessary to clean the castings thoroughly. However, as mentioned before in thimble butt cutting, the use of powder permits the cut to penetrate to a metal body, even though it is coated with a layer of refractory material. In the foundry this consists of sand which frequently adheres

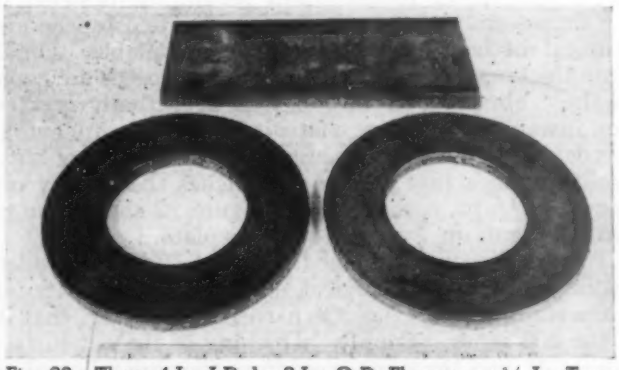

Fig. 22—These 4-In. I.D. by 8-In. O.D. Flanges on 1/2-In. Type 316 Plate Were Made in 2 Minutes Cutting Time Apiece. The 30-Deg. Bevel Was Cut at 20 In. per Minute

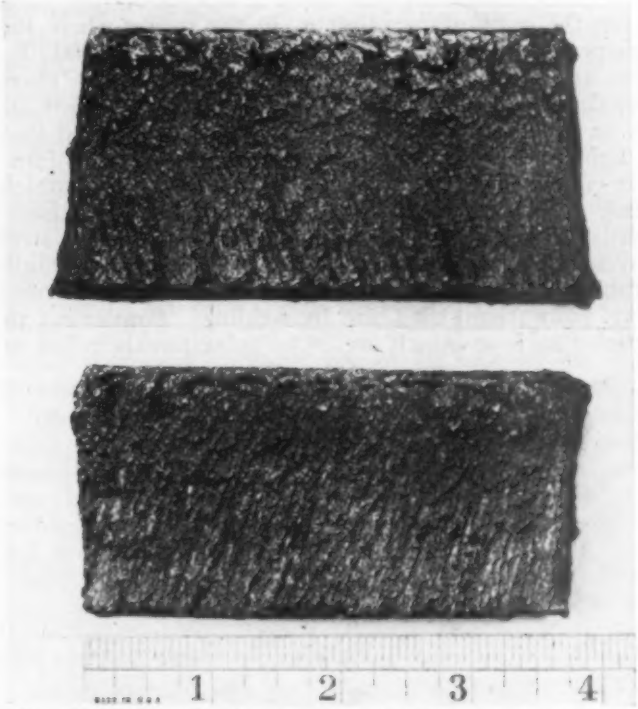

Fig. 23—Powder-Cut Surfaces on a 2-In. Thick *Hastelloy* Material Containing Over 75 Per Cent of Alloying Elements

in corners of the work. Thus with powder-cutting, a rigid cleaning technique prior to riser removal is not necessary. This characteristic of the powder-cutting process will be useful in ordinary carbon-steel foundries for removal of risers prior to sandblasting, thereby increasing the effective sandblasting capacity by eliminating the extra tonnage of the risers that were previously attached to the castings while they were being cleaned.

The fabricator or warehouser of stainless steel will find the process particularly useful, for it will permit them to cut or fabricate sections that were heavier than the capacity of their shearing equipment. It will also speed up contour- or shape-cutting as shown in Fig. 19, which previously would be done on band saws. For very thin stainless steel plates in the range up to 1/4 in. thick, better edge cuts will result if stack-cutting is employed as shown in Figs. 20 and 21. Because of the high heat reaction, tight clamping of the plates is not necessary as the reaction will jump over any ordinary gaps between plates. All plates below the top will have extremely sharp edges. Waster plate shape-cutting can readily be accomplished with the machine-cutting attachments merely by mounting them on standard shape-cutting machines. Beveled edges for welding are as easily produced as square edge cuts. The use of the process in the fabricating industry will permit the designer to use shapes and designs previously prevented by the mechanical methods of cutting that were available. On all plate thicknesses up to 1 in., the cutting speeds are equal to those obtained on carbon steel or actually greater. For instance, on 1/2-in. plate it is possible to cut at speeds of 20 to 24 in. per min. and obtain a very high-quality surface that closely approaches the quality obtained on 1/2-in. carbon steel. Figure 22 shows flanges and bevel cuts on Type 316 stainless plate.

The question will be asked as to the effect of powder-cutting on the metallurgical qualities of the material. If the stainless steel is of the hardenable variety, that is, of the 400 series, naturally hardening of the cut surface will result, and the same procedures that are followed on low-alloy steel plate to prevent its cracking will have to be followed here. As far as corrosion resistance on unstabilized material is concerned, a small amount of carbide precipitation has been noted at a depth of 1/8 to 1/4 in. from the cut surface; that is, in the region where the temperature gradient was between 1000 and 1500° F., the critical temperature range for this material. There is a thin fused layer on the actual cut surface, 0.005–0.007 in. in depth on 1/2-in. plate, and it is recommended that a light grinding pass be made across the surface. Powder-cut areas on unstabilized materials from which scale and fused metal have been removed will satisfactorily withstand any service in which the as-welded steel gives satisfactory performance. Columbium or titanium stabilized materials are not affected by powder-cutting any more than they are by welding. Powder-cut or scarfed surfaces which are to be subsequently rolled or forged require no special treatment inasmuch as the subsequent heating operations will put the material in its original condition.

In addition to the applications previously mentioned, certain specialized applications exist in the field of cast iron, high-alloy, and nonferrous materials.

Although cast iron is not ordinarily classified as an oxidation-resistant material, it nevertheless requires a specialized oscillation technique in cutting with standard oxyacetylene equipment, because of the presence of graphite flakes. With powder, it is possible to cut cast iron as easily as stainless steel. For any given thickness the oxygen- and powder-flow requirements are roughly equivalent to the stainless steel figures, but the cutting speed is reduced approximately 50%. To date, the process has been used most extensively in a large cast iron ingot-mold foundry for the removal of lumps that are the result of mold failure. In some cases the lumps require a depth of cut of 18 inches. The process permits reclamation of molds that would otherwise be considered scrap and offers attractive savings over removal of the lumps by chipping methods.

In the A.I.S.I. listings of stainless steels, Type 310 contains the largest percentage of alloy content, about 45 per cent. There are, however, numerous materials of higher alloy content that have the properties of extremely high corrosion resistance and high strength at high temperatures. These materials, such as the *Hastelloy* alloys, are being cut as a production operation. Figure 23 shows cuts on a *Hastelloy* alloy that contains over 75% of alloying elements. During the war, alloys for jet engines or gas turbines were successfully handled. On alloys such as these, the powder-flow requirements are higher and the cutting speeds somewhat lower than those obtained on equivalent thicknesses of 18–8 stainless steel. It can be seen that high-alloy content provides no limitation on the application of the process.

Nickel-base alloys, such as Monel and Inconel, as well as pure nickel itself, have also been successfully cut up to a maximum thickness of 5 in. With these materials, advantage is taken of the extremely high-temperature reaction between the powder and the cutting-oxygen stream, since the cutting action on these materials is primarily one of melting rather than oxidation. The cut surface quality is somewhat inferior to that on stainless steel.

Since the commercial introduction of the process almost two years ago, its use has expanded until the active users on all the applications mentioned are numbered in the hundreds. The use of a metallic powder provides a versatile process capable of handling a wide variety of alloy compositions with equal facility from ingot form to finished product, and has brought to these materials the same advantages and economies that have been enjoyed in the oxyacetylene processing of carbon steels. By making it easier to produce and process these "hard-to-work" alloys, their use should expand considerably.

Development and Applications of Lime-Ferritic Electrodes*

By D. L. Mathias† and A. P. Bunk‡

Abstract

The ultmate development of an electrode possessing the performance characteristics imparted by the lime-ferritic coating has been considered inevitable for some time. Manufacturing problems and the reluctance of operators to accept electrodes having operating characteristics different from those to which they were accustomed retarded their introduction

While lime-ferritic electrodes in one form or another have found limited application almost since the inception of heavy coated electrodes, their general perfomance left much to be desired. Lime-ferritic electrodes having marked improvements over their predecessors are presented with the belief that they are the forerunners of electrodes embodying new ideas of design.

This lime-ferritic electrode has definite advantages over the conventional heavy coated types. However, certain shortcomings have necessitated the use of a modified technique which has slowed field acceptance. The favorable impact properties at low temperatures possessed by this electrode, together with its ability to satisfactorily weld steels heretofore considered unweldable, has established for this type a unique position in the welding industry as one of the most universal electrodes available today. For example, high sulphur steels, air-hardening steels, and complex alloy steels are readily welded with this electrode. In spite of the advantages cited, the lime-ferritic electrode is not intended to be a panacea for every welding problem. Its development, nevertheless, is a step in reaching the ultimate objective: To produce an electrode capable of welding a variety of steels under highly diversified conditions.

This report compares the low-temperature impact properties of the unalloyed lime-ferritic weld deposit with the conventional heavy coated E-6020 weld deposit in the temperature range 20° C. to −80° C. and shows that a change in type of fracture occurs at approximately −30° C. for the lime-ferritic deposit.

Introduction

"Lime-Ferritic Electrodes" is an expression which came into rather wide use during the recent war, and to many, unfamiliar with history of metallic-arc welding, this type of electrode is regarded as a product of the intensive research and development of that period.

Although it is a coincidence that the perfection of lime-ferritic electrodes in their present form ran concurrently with welding activities in the prosecution of the war, similarly constituted electrodes are almost, if not actually, as old as the first commercially used covered electrode. Conception of present formulation was prewar. The wartime volume fabrication of difficult-to-weld steels and assemblies made possible their introduction under conditions more favorable than during normal times.

The successful welding of steels that were previously considered to be unweldable has brought justly deserved recognition to an electrode based upon fundamentally sound metallurgical principles and which is destined to play an even greater part in promoting welding in peace than it did during war.

In the opinion of the authors, the successful development of the lime-ferritic electrode is one of the outstanding achievements in the field of metallic-arc welding for it embodies a basic principle which is bound to be incorporated to an increasing degree as electrode types are extended. The exacting requirements of postwar specifications; increased use of alloy steels and the influence of wartime scrap have definitely established this statement.

Numerous writers have likened the arc of the covered electrode to the electric furnace. To quote an authority on the electric process for steel making, "It permits oxidizing, reducing and neutral operations to be carried out at will." One could scarcely conceive of the case in which it would be desirable to alter the oxidizing or reducing character of the arc during welding. But the ability to design into an electrode a reducing or neutral character that will remain reasonably constant under normal conditions of use (and at the same time provide adequate fusion and soundness) is essential to quality of welding. It is these features of the electric process of steel making the lime-ferritic electrode possesses that differentiate it from those of conventional design and which have extended arc welding to hitherto unconquered fields.

Introduction of the lime-ferritic electrode has, no doubt, prompted the question, why do we need another electrode? A glance at any electrode catalog reveals such a wide variety that it would seem at least one should meet any possible requirement.

Conventional electrodes, in spite of the impressive array available, leave much to be desired for the welding of certain classes of steels. These steels are daily coming into more extensive use and it is essential that suitable electrodes be made available for their fabrication. In addition to the capacity to weld steels previously considered unweldable, the lime-ferritic electrode deposits metal possessing physical properties superior to that previously obtained.

The history of electrode development and the events along its course have been interesting. The two basic types, from which all our present electrodes were designed had their origin on different continents. The cellulosic or organic type is a product of American research while the mineral originated in Europe from where it was introduced to America. Vast improvements have been made in the intervening period for the electrodes of today are a far cry from those of Stressau and Kjellberg who laid the foundation of the welding industry.

As an introduction to a discussion of the chemistry and metallurgy of the basic conventional electrode type fluxes, the functions of an electrode coating are as follows:

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(*a*) To stabilize the arc through the formation of a highly ionized vapor or gas surrounding the arc.

(*b*) To control the melting rate of the electrode and the penetration of the base metal by altering the distribution of thermal energy in the arc.

(*c*) To prevent atmospheric contamination of the deposited weld metal by the formation of a vapor or gaseous envelope or shield around the arc and/or adequate slag blanket over the deposit.

(*d*) To supply weld metal of the desired composition either by maintaining the original composition of the core wire or through the introduction of additional elements.

(*e*) To retain the weld metal in a fluid condition, by means of a blanket of slag, long enough to allow for evolution of contained gases and the separation of nonmetallic impurities.

Conventional electrodes were previously referred to as leaving much to be desired, especially for the welding of certain classes of steel. The manifestations of their performance deficiencies might be stated as follows:

1. Their inability to weld different varieties of plain low-carbon steels, such as rimmed and killed steels, without a variable degree of reaction pitting and X-ray porosity unless the flux coating is formulated for the specific steel upon which it is being used.
2. Their inability to allow the introduction of reducing type of alloy additions such as silicon, manganese, chromium, vanadium, etc., without badly upsetting performance characteristics. A heavy loss of these elements results, and their state of combination in the weld is always questionable.
3. Their inability to weld free machining steels without surface and X-ray porosity and weld cracking.
4. Their inability to weld drastically air hardening steels without the formation of under-bead cracking unless preheated.

Organic Electrodes

Organic electrodes, generally referred to as cellulosic rods, and given the A.W.S.-A.S.T.M. designation Exx10 and Exx11, find their greatest application to out-of-position welding where the high heat input and volume and fluidity of slag of the mineral electrode make the latter very difficult to handle. Merely reducing the flux diameter of mineral type electrodes without slag adjustment and better arc protection is insufficient to adapt them to all position welding. Furthermore, reduction of flux diameter reduces arc drive to such an extent that manipulation of the electrode during welding is seriously impaired.

For all position welding electrodes, incorporation of a substantial quantity of organic material into the flux gives adequate protection to the arc-stream, provides the necessary drive for ease of manipulation and, being combustible, reduces the volume of slag produced. Because of the rapid solidification of the deposit required to make out-of-position welding possible and the nature of the gaseous envelope surrounding the arc-stream, welds deposited with organic electrodes are inferior to those of mineral electrodes in so far as porosity and slag inclusions are concerned. They do, however, possess excellent physical properties in spite of the porosity.

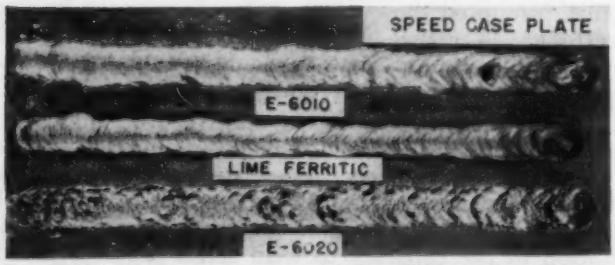


Fig. 1(*A*)—Reaction Pitting: $^{3}/_{16}$-In. E-6010, Lime-Ferritic and E-6020 Electrodes Deposited on 0.20% C, 1.26% Mn, 0.29% S Plate

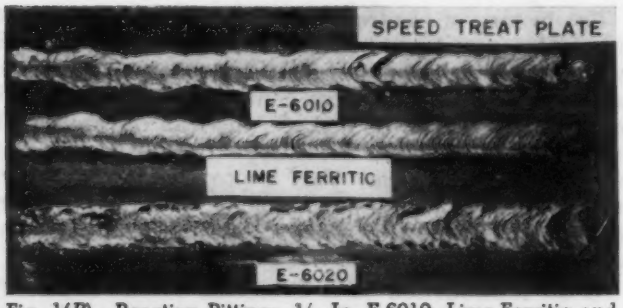


Fig. 1(*B*)—Reaction Pitting: $^{3}/_{16}$-In. E-6010, Lime-Ferritic and E-6020 Electrodes Deposited on 0.54 C, 1.10% Mn, 0.22% S Plate

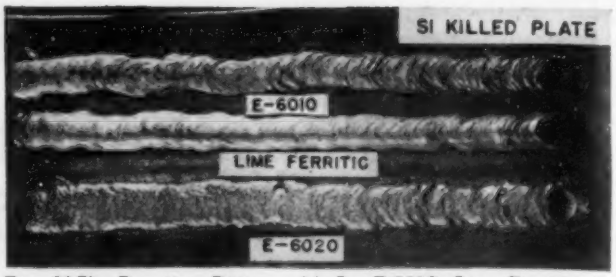


Fig. 2(*A*)—Reaction Pitting: $^{3}/_{16}$-In. E-6010, Lime-Ferritic, E-6020 Electrodes Deposited on Si Killed Plate

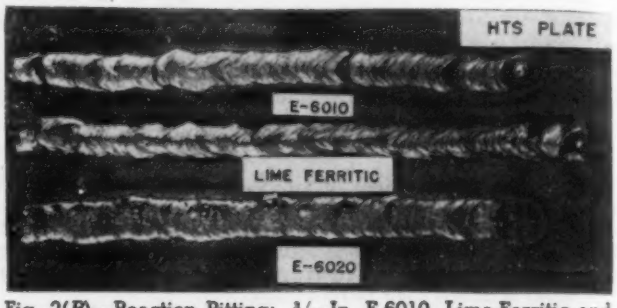


Fig. 2(*B*)—Reaction Pitting: $^{3}/_{16}$-In. E-6010, Lime-Ferritic and E-6020 Electrodes Deposited on High-Tensile Steel Plate

Mineral Electrodes

Mineral type electrodes, frequently referred to as "hot rods," and given the A.W.S.-A.S.T.M. designations Exx20 and Exx30 are used for the fabrication of weldments requiring the utmost in weld quality. This quality is attained by absence of organic gas-forming materials, high heat input and a substantial volume of fluid slag. These factors combine to retard the cooling rate of the deposit thereby affording sufficient time for the escape of dissolved gases and the coalescence of emulsified slag and its ultimate separation from the weld.

By comparison with organic electrodes, mineral electrodes produce a relatively small volume of gas for protection against attack. However, this small volume is effectively used because of the deep crucible formed at the arcing end of the electrode and its protective influence is supplemented by the heavy blanket of slag over the deposit. Although the nitrogen pickup of welds made with mineral electrodes is somewhat greater than

that of organic electrodes, it is beneficial in improving the strength without adversely influencing ductility.

Chemistry and Metallurgy of Organic Electrodes

With this brief introduction covering the general performance characteristics of mineral and organic electrodes, let us look into the chemistry of the coatings and metallurgy of the deposits of the two types. The essential constituents of mineral and organic fluxes are as shown in Table 1.

Table 1—Essential Constituents of Mineral and Organic Fluxes

Mineral Flux	Organic Flux
Slag Formers	
Iron Oxide	Titanium Dioxide
Manganese Oxide	Magnesium Carbonate
Feldspar—Mica	Feldspar
Asbestos	Asbestos
Silica	Clay
	Silica
Deoxidizer	
Ferromanganese	Ferromanganese
Ferro-Silicon	
Silico-Manganese	
Shielding	
Organic	Carbohydrate—Cellulose
Binder	
Soluble Silicate	Soluble Silicate Binder

It is necessary to make provision in flux formulation to eliminate its detrimental effects. Introduction of combined water compounds which yield water at high temperature, provide the necessary control. Upon release of the combined water, it immediately dissociates into hydrogen and oxygen, carbon being oxidized to carbon-monoxide in the familiar water-gas reaction.

The large amount of water released from the binder and/or combined water compounds and subsequently dissociated not only serves to control decomposition of the organic flux constituent but also oxidizes a large portion of the ferromanganese added to the flux as a deoxidizer at the same time oxidizing a portion of iron from core, weld and base metal. These oxides then enter the slag and influence its fluidity in a manner similar to that of mineral electrodes but to a lesser degree. In spite of the oxidizing conditions that result in the formation of iron and manganese oxides, an appreciable amount of silica is reduced by the carbon residue to metallic silicon and enters the deposit as such.

It is obvious that the extent to which these reactions take place varies not only from beginning to end of an electrode as it heats up during welding, but is also a function of the welding current. Other variables which influence the extent of these reactions are the free water content as influenced by conditions of storage and the ability to retain this water during welding for the intended purpose.

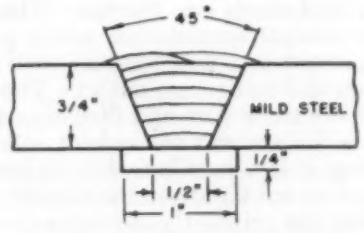
As in the case of mineral electrodes, but to a lesser degree, the ability to introduce alloying elements and to control the composition of organic electrode deposits is a problem of some magnitude. It is also difficult to control operating characteristics when we stop to consider that water, which serves to destabilize the arc, is a major constituent of the flux. Organic electrodes are equally sensitive to the presence of sulphur and selenium for the same reasons as discussed under mineral electrodes.

Chemistry and Metallurgy of Mineral Electrodes

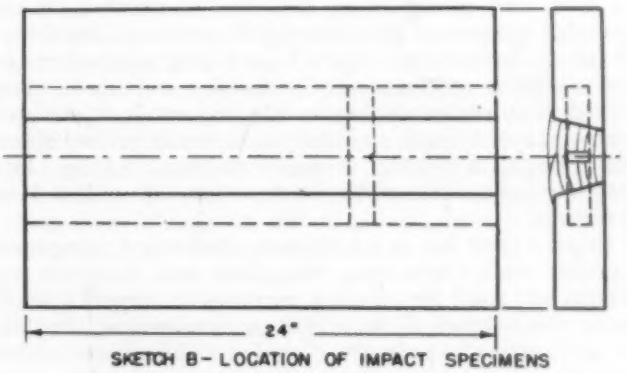
So complex is the mechanism of an electrode flux that it is impossible to assign a single and definite function to any one of the constituents of either type of flux. As an example, a deoxidizer is not regarded as an arc stabilizer, yet variaton of the particle size of such a material is known from experience to have a pronounced influence upon arc action. Similarly, the state of combination of so potent an arc stabilizer as potassium oxide may be so altered as to impair rather than improve arc stability. With the exception of the organic constituent, several of the alloying additions and the combined or retained water, all flux materials enter the resultant slag to some extent although their state of combination may be altered during fusion. Organic materials, the combined water of hydrated compounds and the retained water of the binder while theoretically converted to gases during welding influence both the chemistry of the coating and slag as well as the metallurgy of the weld.

Good mineral coated electrodes of the conventional type leave little to be desired when used for the welding of steels for which they were designed or for which they can be adapted. The major factor preventing more general use without modification is the employment of iron and/or manganese oxides as slag fluidifiers. Their use influences electrode performance with respect to weld quality in the presence of powerful deoxidizers in the flux or base metal and the presence of such elements as sulphur or selenium whether they are present as impurities in core, flux or base metal.

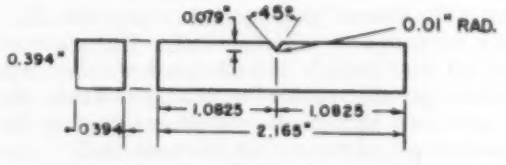
The term deoxidizer above is used collectively to cover elements intended solely to deoxidize the weld deposit as well as to those which are deoxidizing with respect to



SKETCH A- JOINT PREPARATION



SKETCH B- LOCATION OF IMPACT SPECIMENS



SPECIFICATION FOR IMPACT SPECIMEN

Fig. 3

E-6020 Weld

Lime-Ferritic Weld

Fig. 4—Typical Macrosections of Welds Made with E-6020 and Lime-Ferritic Electrodes

the oxides of iron and manganese in the slag when their intended use was only as alloying additions for the purpose of imparting definite properties to the weld. A glance at a table showing the heats of formation of metal oxides will disclose that most of the elements used either as deoxidizers or alloying additions to the steel have higher heats of formation than those of iron and manganese. Among the exceptions are the alloying elements nickel and molybdenum, which do not adversely affect electrode performance however present.

The steel in the molten pool of weld metal dissolves FeO from the slag with which it is in contact. The solubility of FeO in the steel is a function of temperature and FeO content in the slag. As the fluidity of the electrode slag is controlled by the content of iron and manganese oxides it contains, solubility of FeO is unavoidable. Whatever degree of deoxidation of the deposit that can be obtained must be accomplished by introduction of the deoxidizers into the flux. Thus we have a seemingly paradoxical formulation where powerful deoxidizers are present in a flux together with such strong oxidizers as iron and manganese oxides. Throughout the melting of the electrode core and flux, transfer of metal and slag across the arc and subsequent solidification of deposit and slag, it is a race between the oxygen of the flux, slag and air on one hand and the deposit on the other as to which wins the prize—the deoxidizer.

The only known method of controlling distribution of the reducing effect of the deoxidizer between deposit and slag is through particle size control of the deoxidizer. At best, only about 10 or 15% can be utilized for the intended purpose. Any attempt to increase deoxidizer efficiency beyond this figure upsets slag characteristics and electrode performance is thereby impaired. Dissolved FeO in steel lowers tensile properties at elevated temperatures to such an extent as to result in "red shortness" which, in welding, is manifested by cracking. FeO also reduces resistance to shock or impact at low temperatures.

Beyond their use as deoxidizers, silicon and manganese together with chromium, vanadium and tungsten are extensively used for alloying purposes to impart specific properties to steel. Like silicon and manganese, they are deoxidizers in the presence of iron and manganese oxides. Attempts to introduce these elements into the deposit of mineral electrodes, except in very small amounts, not only results in altered slag characteristics but also in low efficiency of transfer. Furthermore, the state of combination of that which is recovered in the deposit is questionable as test results frequently indicate that substantial portions of the alloy additions exist in the weld in the nonmetallic form rather than alloyed.

Carbon is also capable of altering the performance of mineral electrodes since it reduces the fluidifying oxides of the slag in much the same manner as the other elements just discussed. Its products of reaction are gaseous and do not enter the slag, hence the detrimental influence of carbon is somewhat less pronounced than those whose product of oxidation are solids and which enter the slag by replacement.

Sulphur and selenium, whether present as impurities or as intentional additions, are sources of serious trouble. They combine with iron to form sulphide and selenide, respectively, which produce "red-shortness" resulting in weld cracks. Combined with manganese rather than with iron, their detrimental influence is almost completely eliminated. The oxidizing character of mineral electrodes makes it impossible to effect a high enough state of deoxidation to permit the introduction of sufficient metallic manganese to counteract the effect of these elements. In addition to their crack producing propensities, sulphur and selenium under oxidizing conditions are readily converted to their gaseous oxides resulting in weld porosity.

What is the solution for the deficiencies of conventional electrodes as first enumerated? The lime-ferritic electrode provides the answer to those special welding applications for which conventional electrodes fail to give optimum results.

The name sounds a bit mysterious but its derivation is quite simple. Limestone or calcium carbonate as it is chemically known, is the major constituent of the flux coating. During welding the limestone is decomposed with the liberation of carbon dioxide and the formation of calcium oxide or lime. As the flux formulation follows much the same pattern as that of stainless electrodes, the word "ferritic," descriptive of the metallurgical character of the weld deposit, is appended to the word "lime" to differentiate them from austenitic electrodes; hence, "lime-ferritic."

In addition to limestone, other essential ingredients of the flux are fluorspar, deoxidizer and/or alloying elements stabilizers, slag modifiers and binder solids. Readily reducible oxides, organic materials, combined water compounds and retained water are not employed. The flux is strictly mineral in character.

Elimination of the organic and associated constituents of the XX10 type electrode flux and the reducible oxides of the XX20 type, with the limitations they impose; chemical and metallurgical reactions are reduced to their simplest possible form.

Adequate protection against atmospheric contamination is provided by carbon-dioxide–carbon-monoxide gases resulting from decomposition of the limestone. The resulting lime, fluxed by the fluorspar, provides a nonreducible basic slag permitting a high degree of deoxidation of the weld deposit, thereby minimizing or

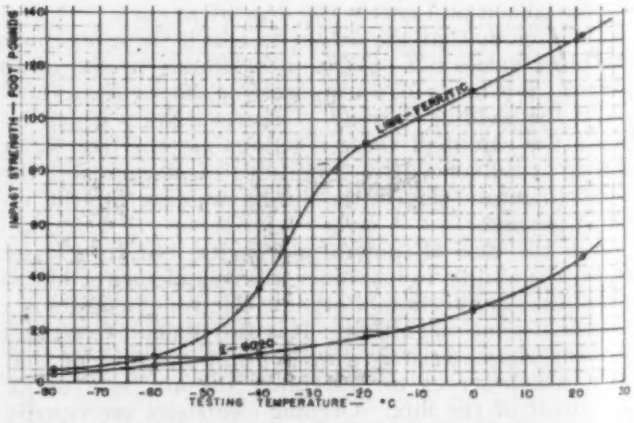


Fig. 5. Effect of Testing Temperature Upon Impact Strength of Lime-Ferritic and E-6020 Weld Deposits

Table 2—Typical Lime-Ferritic Electrodes

	A	B	C	D	E	F
Chemical Analysis of Weld Deposit						
Carbon, %	0.06–0.10	0.23–0.26	0.10–0.14	0.09	0.09	0.12
Manganese, %	0.50–0.60	0.70–0.80	1.65–1.85	0.80	0.50	0.68
Silicon, %	0.20–0.30	0.30–0.40	0.25–0.35	0.18	0.24	0.22
Sulphur, %	0.03 max.	0.03 max.	0.03 max.	0.018	0.035	0.03
Phosphorus, %	0.02 max.	0.02 max.	0.02 max.	0.019	0.035	..
Chromium, %	..	..	..	..	0.20	0.90
Nickel, %	..	..	..	2.09	..	..
Molybdenum, %	..	..	0.35–0.45	0.45	0.52	0.45
Physical Properties As-Welded						
Yield point, psi.	59,750	62,500	86,875	..	64,000	..
Ultimate strength, psi.	69,250	82,000	109,060	..	76,000	..
Elongation, % in 2 in.	31.7	34.4	21.9	..	32.0	..
Reduction of area, %	73.5	65.9	53.9	..	66.0	..
Fracture	Cup and cone	Cup and cone	Irregular	..	..	..
Physical Properties Heat-Treated		S. R.	S. R.			
Yield point, psi.	..	55,000	82,500	83,500	45,000	52,000
Ultimate strength, psi.	..	75,000	97,125	95,000	66,000	76,000
Elongation, % in 2 in.	..	34.4	25.4	25.0	35.0	30.7
Reduction of area, %	..	66.1	68.1	78.1	70.0	64.0
		Cup and cone				

eliminating the detrimental effects of ferrous oxide and sulphur. Total phosphorous available from flux, core wire and plate is uneffected but well within desirable limits.

Properties of Lime-Ferritic Electrodes

Typical physical properties and chemical compositions of various alloyed and unalloyed lime-ferritic electrodes are presented in Table 2. In Table 3 the deposition characteristics of unalloyed lime-ferritic and E-6020 class electrodes are presented. A discussion of the low-temperature impact properties is made in the next section of this paper.

Conclusions (As Applied to Applications of Lime-Ferritic Electrodes)

The advantages which lime-ferritic electrodes possess over conventionally formulated electrodes, based on laboratory tests and field acceptance, may be summarized as follows:

1. They possess the ability to weld different varieties of plain low-carbon steel, such as rimmed and killed steels, without a variable degree of reaction pitting and X-ray porosity.

Table 3—Deposition Characteristics of Unalloyed Lime-Ferritic and E-6020 Class Electrodes at Various Currents Using $^5/_{16}$-In. Diameter Electrodes

Amp.	Deposition Rate, Oz./Hr.	Deposition Efficiency, %	Spatter Loss, % of Core	Burn-Off Rate, In./Min.
		Lime-Ferritic		
170	57.78	72.66	−1.63	7.68
210	65.73	72.73	−1.74	8.57
250	71.22	69.80	2.36	9.94
		E-6020 Class		
170	58.32	64.83	15.25	9.00
210	71.14	64.55	15.63	11.03
250	84.68	65.39	14.52	12.95

2. They allow the introduction of reducing type of alloy additions such as silicon, manganese, chromium and vanadium without noticeably upsetting performance characteristics.

3. They possess the ability to weld free machining steels without surface and X-ray porosity and weld cracking.

4. They possess the ability to weld drastically air hardening steels without the formation of underbead cracking.

Low-Temperature Impact

In developing an alloy electrode for special applications as for example low-temperature service products, the electrode formulator has a choice of employing either a mild steel core wire, making the alloy addition through the coating, or he may use an alloy core wire coated with a flux low in alloying elements to give him the desired chemical composition of the weld deposit.

For the purpose of determining the best type of coating, i.e., mineral or lime type for developing alloy electrodes designed for low temperature applications, a comparison was made of the impact properties of the lime-ferritic and E-6020 class weld deposits as affected by low temperatures. A secondary purpose of this investigation was to determine whether or not a difference exists in impact values of weld deposits which have the notch located in the root and the face of the deposit.

Procedure

Test assemblies consisting of two pieces $^3/_4$- x 6- x 24-in. mild steel plate beveled to a 45° included angle along the 24 in. dimension and fitted with a $^1/_4$-in. back-up strip using a $^1/_2$-in. root opening (Fig. 3, Sketch A) were welded with $^3/_{16}$-in. lime-ferritic and E-6020 electrodes operated at 225 amp. using a full weave technique and a 212° F. interpass temperature. In the case of the lime-ferritic electrode nine passes were necessary to completely fill the joint, whereas ten passes were needed with the E-6020 electrode. The completed assemblies were then machined to $^5/_8$ in. thickness in preparation for radiographic examination. Such examination was necessary

to avoid incorporating a defective area if present in the impact specimen. Figure 4 shows macrosections of the deposits. Twenty-seven transverse impact specimens of the Charpy type having an Izod notch located in the weld metal (Fig. 3) were then machined from each assembly and submitted for testing at six temperatures ranging from room temperature to −110° F. The notch direction was chosen perpendicular to the plane of the plate (Fig. 3, Sketch B) so that a number of layers of weld metal were included over the width of the specimen. It was believed that in so doing, more consistent results would be obtained than in having the notch parallel to the direction of welding. Three impact specimens were provided for each testing temperature for each weld deposit. The manner of obtaining low temperatures consisted of immersing the specimens in a solution of dry ice and alcohol and allowing them to remain there for a period of approximately 15 min., after which they were placed in the impact apparatus and tested. The average time consumed in transferring the specimens from the batch to machine was on the order of 3 sec.

In addition to the specimens prepared for the low-temperature test, two sets of three specimens per set were tested at room temperature, one set having the notch located in the face of the joint parallel to the direction of welding and the other set machined with a notch in the root of the joint parallel to the direction of welding.

Results and Discussion

In Table 4 the results of the impact tests as affected by variations in testing temperature are listed.

It may be observed from this table that the lime-ferritic weld deposit has greater energy absorbing ability than the E-6020 weld deposit at all temperatures considered. The plot of these impact values as a function of testing temperature is shown in Fig. 5 and indicates that for the lime-ferritic deposit the impact value falls off rapidly in the temperature range −20° C. to −40° C. This is the range in which the type of fracture changes from ductile to brittle as can be noted in Figs. 6–10. In connection with these photographs it may be noted (and from Table 4 also) that the lime-ferritic weld specimens tested at 20°, 0° and −20° C. were not completely fractured into two pieces but absorbed the full blow of the impact resulting in a V-shaped specimen held together at the apex by a thin layer of metal. These specimens show a fibrous, ductile fracture, whereas those tested at −40° and −60° C. show a crystalline brittle fracture

Table 4—Effect of Testing Temperature Upon Impact Values of 3/16-In. Lime-Ferritic and E-6020 Weld Deposits

Standard Charpy Specimen with Izod Notch Normal to Plane of Plate

Electrode	Test, ° C.	Temp., ° F.	Energy Absorbed, Ft.-Lb.	Av. Energy Absorbed,* Ft.-Lb.	Ratio†
Lime-ferritic	22	71.6	127 NB 132 NB 139 NB	132.8	
					2.75
E-6020	22	71.6	48 49 49	48.3	
Lime-ferritic	0	32	115 NB 103 NB 115 NB	110.7	
					3.89
E-6020	0	32	40 22 23	28.5	
Lime ferritic	−20	−4	113 NB 62 NB 100 NB	91.6	
					5.08
E 6020	−20	−4	21 18 16	18.0	
Lime ferritic	−40	−40	39 41 28	35.9	
					3.07
E 6020	−40	−40	13 10 12	11.7	
Lime ferritic	−60	−76	5 8 15	9.3	
					1.25
E 6020	−60	−76	10 8 4	7.4	
Lime ferritic	−78	−108.4	8 3 5	5.2	
					1.62
E 6020	−78	−108.4	1 3 5	3.2	

* Computed from individual values before rounding off to nearest ft.-lb.
† Represents the ratio of the average energy absorbed by lime-ferritic to average energy absorbed by E-6020.
NB Specimen did not fracture into two pieces.

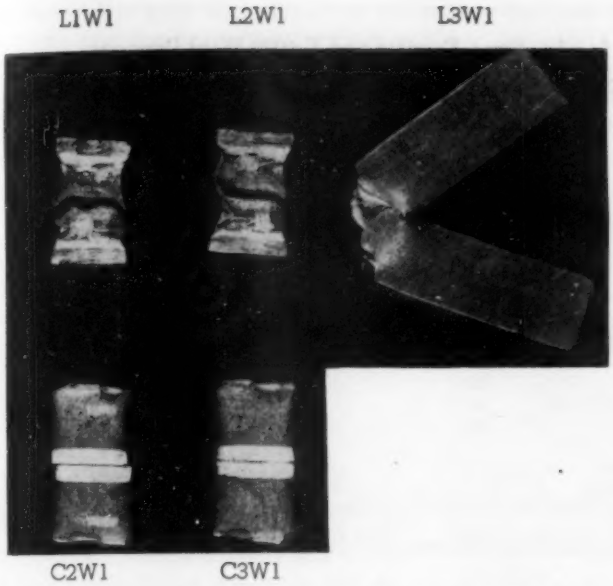


Fig. 6—Fractures Produced in Weld Deposits of Lime-Ferritic (L Series) and E-6020 (C Series) Electrodes. Specimens Tested at 20° C.

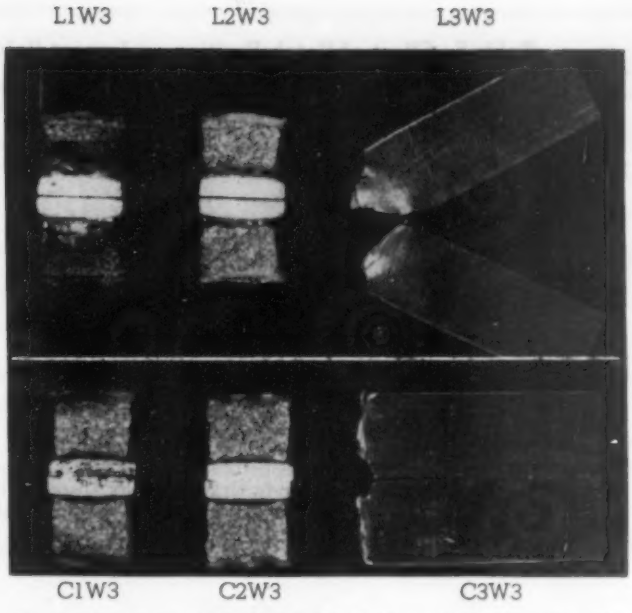


Fig. 8—Fractions Produced in Weld Deposits of Lime-Ferritic (L Series) and E-6020 (C Series) Electrodes. Specimens Tested at —20° C.

with complete separation of the impact specimens into two separate parts.

On the other hand, impact results for the E-6020 weld deposits, indicated in Table 4 and Fig. 5, show that the absorbed energy was considerably below that of the lime-ferritic deposit in the temperature ranges 20° C. to −40° C. It may be further observed from the curve of impact energy vs. testing temperature that the E-6020 weld deposit does not undergo a transition from a ductile type of fracture to a brittle one over the range of temperatures investigated as was the case for the lime-ferritic weld deposit. Inspection of Figs. 6–10 show that a fine-grained, brittle fracture occurred for all temperatures, there being little indication that those tested at room temperature were able to absorb more energy than those tested at lower temperatures.

In Table 5, the effect of the position of the notch in the weld upon the impact properties at room temperature is shown. One set of specimens for each electrode deposit was notched in the face of the weld (after plate was machined to $^5/_8$ in. thickness for X-ray) parallel to the direction of welding and one set was prepared with the notch in the root of the weld parallel to the direction of welding. These specimens were tested at room temperature.

It may be observed for both lime-ferritic and E-6020 weld deposits that the difference in impact value between specimens notched in the face of the weld and root of the weld was less than the experimental error.

Figures 11 and 12 consist of photomicrographs of the weld metal of the lime-ferritic and E-6020 weld deposits.

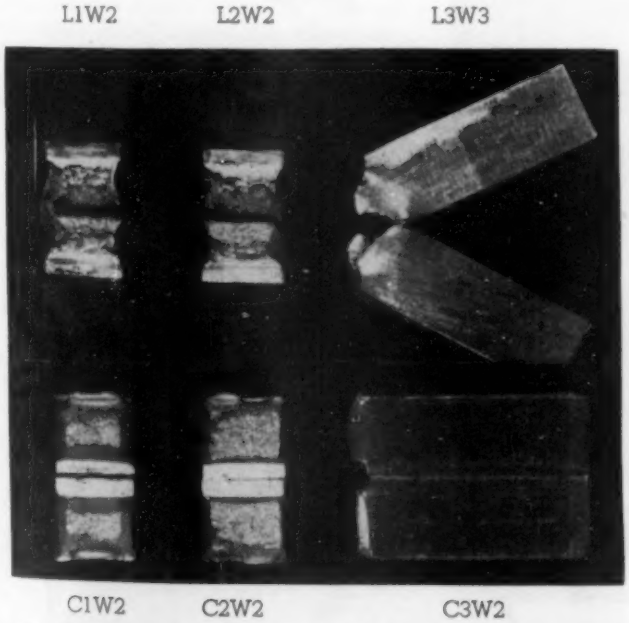


Fig. 7—Fractures Produced in Weld Deposits of Lime-Ferritic (L Series) and E-6020 (C Series) Electrodes. Specimens Tested at 0° C.

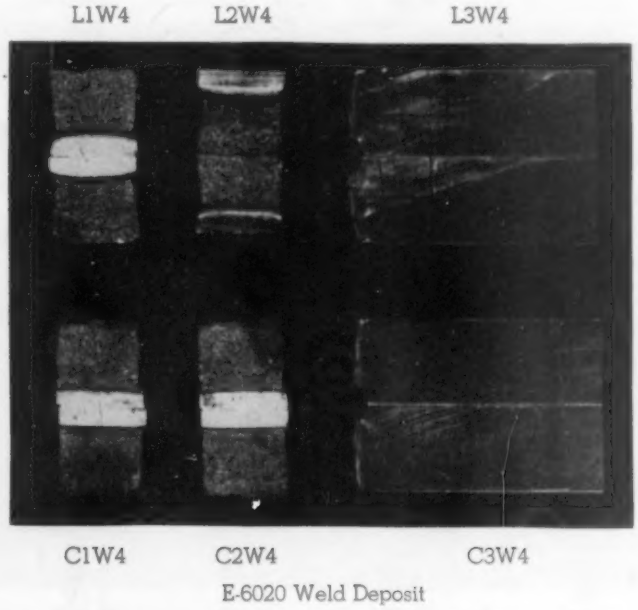


Fig. 9—Fractures Produced in Weld Deposits of Lime-Ferritic (L Series) and E-6020 (C Series) Electrodes. Specimens Tested at —40° C.

Table 5—Effect of Notch Position on Impact Values of 3/16-In. Lime-Ferritic and E-6020 Weld Deposits

Standard Charpy Specimen with Izod Notch Parallel to Welding Direction

Electrode	Notch Location	Testing Temp.	Energy Absorbed, Ft.-Lb.	Av. Energy Absorbed,* Ft.-Lb.	Ratio†
Lime-ferritic	Face	22° C. (71.6° F.)	140 NB 143 NB 144 NB	142.4	
					3.34
E-6020	Face	22° C. (71.6° F.)	47 38	42.7	
Lime-ferritic	Root	22° C. (71.6° F.)	142 137 144	140.9	
					3.01
E-6020	Root	22° C. (71.6° F.)	51 40 49	46.7	

* Computed from individual values before rounding off to nearest ft.-lb.
† Ratio of energy absorbed by lime-ferritic to energy absorbed by E-6020.
NB Specimens did not break in two but held together by a thin metal layer.

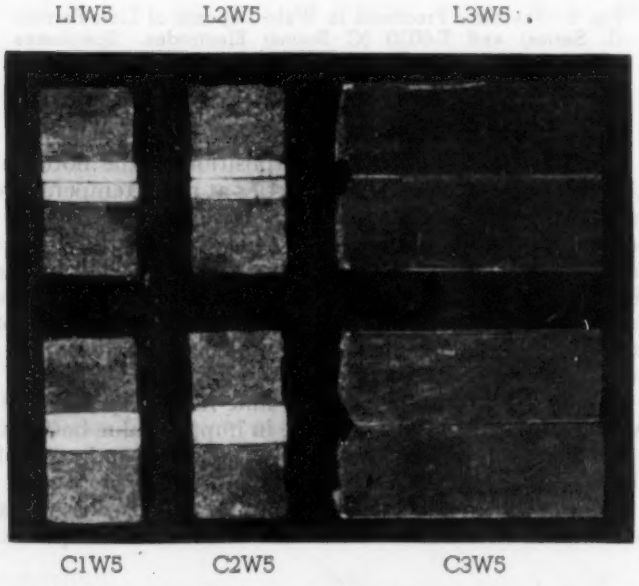


Fig. 10—Fractures Produced in Weld Deposits of Lime-Ferritic (L Series) and E-6020 (C Series) Electrodes. Specimens Tested at —60° C.

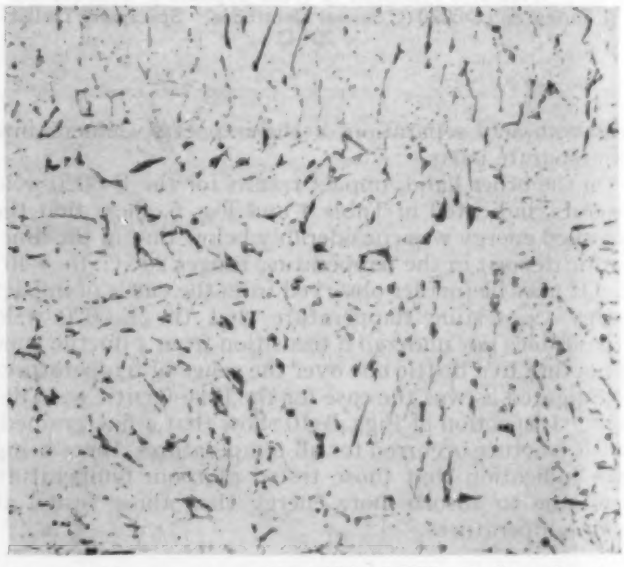


Fig. 11—Microstructure of Weld Metal (500 ×); Lime-Ferritic Electrode

In Table 6 chemical analyses of the weld metal and the base metal are presented.

Conclusions (Applied to Low-Temperature Impact)

1. Lime-ferritic weld deposits show a transition from ductile to brittle type of fracture under impact at approximately −30° C. In the temperature range −30° C. to +20° C. the impact values of the lime-ferritic weld deposits are vastly superior to E-6020 weld deposits.

Table 6—Chemical Analyses of Base Metal and Weld Deposits of 3/16-In. Lime-Ferritic and E-6020 Electrodes

Element	Lime-Ferritic	E-6020	Base Metal
C	0.07	0.10	0.20
Mn	0.62	0.34	0.42
Si	0.26	0.02	0.09
S	0.02	0.03	0.029
P	0.02	0.02	0.019

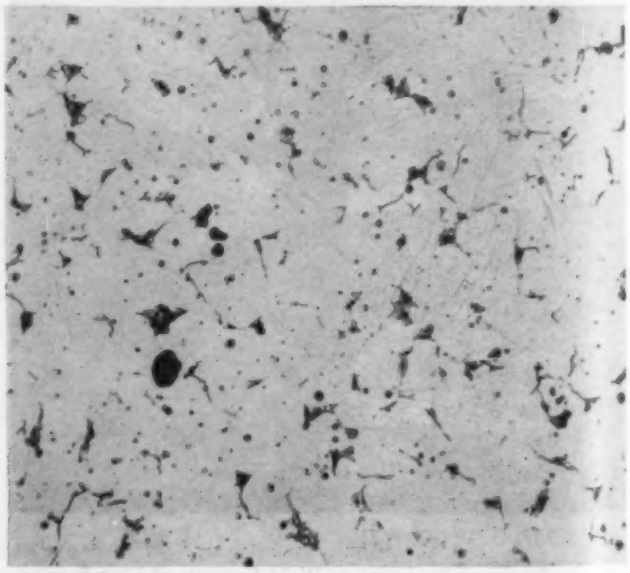


Fig. 12—Microstructure of Weld Metal (500 ×); E-6020 Electrode

2. E-6020 weld deposits show no change in type of fracture over the temperature range −80° C. to +20° C.

3. Notch locations in the weld metal appear to have no influence on the impact properties of lime-ferritic and E-6020 weld deposits at room temperature as far as this test is concerned.

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Spot Welding Under Water

By Charles L. Coomer*

WHILE the practice of spot welding under water has been followed only to a limited extent by industry as a whole up to this time, it may well be the solution to many a manufacturer's problem in these days of material shortages and rising production costs. The savings realized by the American Air Filter Co. in the application of this welding technique have convinced those of us in the engineering and production departments of the ultimate economy in the purchase of necessary additions to our spot welding equipment to broaden its application—especially in the manufacture of our dust control products.

Our experience with spot welding under water began 15 yr. ago—in the days when it was practically unheard of. A sizable increase in the sales volume of a particular model of our Roto-Clone dust control equpment brought about its application. The Roto-Clone employs the principle of dynamic precipitation and comprises a housing with a primary and secondary air passage and a turbine-like impeller with a large number of carefully calculated hyperboloid blades. The rotating impeller creates the necessary forces to draw in the dust-laden air, separate the dust and discharge the cleaned air. The collected dust passes into a hopper base which acts as a storage bin.

The impeller of the type Roto-Clone referred to consists of a concave disk of 1/8-in. mild rolled steel, for the smaller diameters, ranging up to 1/4-in. thickness for the largest diameter. The blades are of cold-rolled steel, 0.050 in thickness. The spacing of the blades as well as their pitch is carefully calculated in accordance with the size of the dust particles to be collected and removed from the airstream. Revolving at high speeds, the over-all balance of the impeller is vitally important to the efficiency and maintenance of the dust collector as a whole. Drilling the disks and riveting the blades not only created serious production bottlenecks but was highly inaccurate. The normal variations in the hardness of the steel blades disturbed the angle in riveting, thus accurate spacing was impossible. Each impeller, upon completion, had to be respaced by hand and left to the inaccuracy of the human eye. Spot welding was obviously the answer.

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Guide Charts Using Taylor Spot Welder with Water on Roto-Clone Impellers

Impeller Diameters, In.	Blade Thickness	Disk Thickness	Tap Adjustment	Approx. Time of Weld, Sec.
6-9-11 1/4	0.050 cold-rolled steel	1/8-in. mild rolled steel	No. 4	0.6
7 1/2-18-22 1/2	0.050 cold-rolled steel	To 3/16-in. mild rolled steel	No. 6	0.9
27-32	0.050 cold-rolled steel	To 1/4-in. mild rolled steel	No. 8	1.2

The initial spot welding applications were made without water and the results, while much better than the slow and costly drilling-riveting operation, were far from satisfactory. The amount of heat necessary to properly weld the comparatively thin blade to the thick disk caused many welds to burn through the blades; furthermore, the distortion in the disk due to the extreme heat demonstrated the need for an application that would leave the impeller in balance for a necessary minimum tip speed of 9000 ft. per minute and a maximum of 16,000 ft. per minute. Then too, the life of the electrodes was materially reduced. The use of water not only eliminated defective welds and disk distortion but increased the life of the electrodes 10 to 15 times.

The equipment used in this operation is a Taylor Spot Welder, 20 kw., 220 v. with a General Electric Timer, CR-7504A, with electronic tube time delay and a range from 0 to 1.25 sec. The electrode

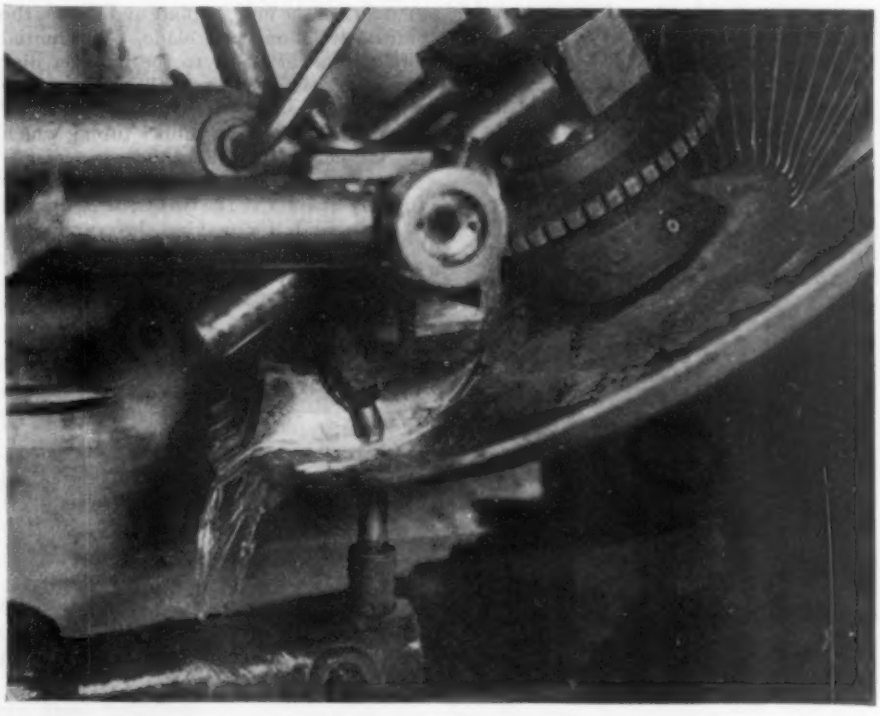

Fig. 1—In Making Successive Welds on the Blade, the Carriage Swings in an Arc. After the Initial Weld, the Blade Is Positioned and the Index "Finger" and Plates Are No Longer Needed

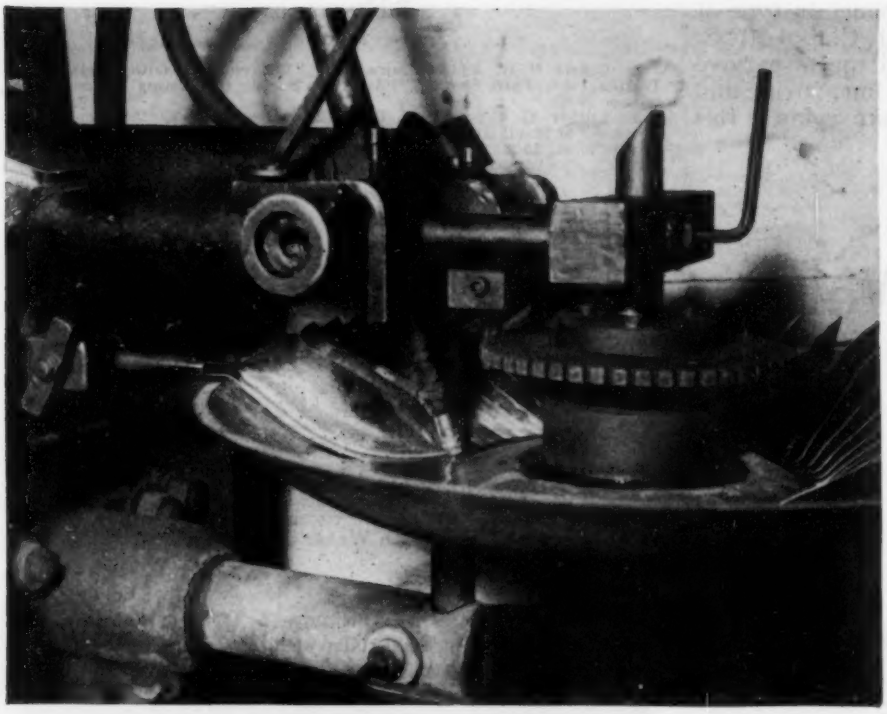

Fig. 2—Notched Index "Finger" on Face of Spot Welder Holding Extended Tip of Impeller Blade and Top Electrode in Position for the Initial Weld Act as a Jig. The Water Is Then Applied and Successive Welds Are Made

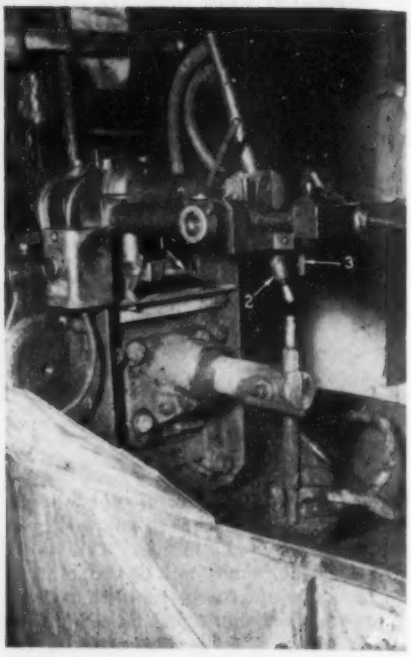

Fig. 3—(1) Adjustable, Notched Index "Finger"; (2) Water Line Is Clamped to Top Electrode Approximately 2 In. Above the Tip; (3) Square-Edged Pawl Which Fits Into Indexer Plate When Positioning Blades

material is Mallory 3, the top electrode being $^{5}/_{8}$ in. in diameter tapering to $^{3}/_{16}$ in. with a 5-in. radius. The bottom electrode is also a $^{5}/_{8}$-in. diameter tapering to $^{1}/_{4}$ in. with a 6-in. radius.

In designing the fixture it was necessary to keep three fundamentals in mind:

1. A foolproof indexer for accurately spacing the blades.
2. An adequate jig to hold the blade in position until at least one weld had been made.
3. A carriage that would operate without disturbing the adjustments of the jig or the indexer while making the successive welds.

There are eight impeller sizes, the disks ranging from 6 to 32 in. in diameter. Since the contour of the disk for each size impeller varies, the carriage is adjustable to maintain the proper line of travel so that the material is always at right angles to the welding tips. The indexer plates are square-notched metal disks—one for each impeller size—with a collar assembly which is fitted to the opening in the center of the impeller disk and through which is placed the carriage shaft. To the rear of the electrodes on the face of the welder is an adjustable notched index "finger" which aligns the extended tip of the blade. Directly in front of the top electrode is a square-edged pawl which fits in the notches of the indexer plate and locates the initial weld on each blade. This initial weld fixes the blade to the impeller disk and the operator merely tilts the carriage to make the successive welds. The water is supplied by $^{3}/_{4}$-in. rubber tubing which is clamped to the side of the top electrode and enters the operation at a point approximately 2 in. above the tip of the electrode.

As a guide for making the correct adjustments to the fixture, one blade is positioned and riveted to the disk. On most of these Roto-Clone models, the impellers are designed for close blade settings and there is not enough clearance for the electrode to properly weld the last blade. Therefore, an additional set of holes are drilled adjacent to the guide blade for riveting the final blade to complete the job.

Savings in connection with the application are indeed worth mentioning. One man performs this operation replacing the 3 men formerly needed—2 for the riveting operation and 1 for the drilling operation—at a saving of approximately 60% in manufacturing costs.

Stainless steel has found its way into the manufacture of many special Roto-Clone models because of its resistance to corrosive action. Here again, spot welding under water has proved highly successful. It is perhaps with the increased use of this material and the constant pressure to cut those manufacturing costs that we will see this most significant welding procedure followed to a much greater extent.

Building Code Requirements for Welding Structural Steel

By Simon A. Greenberg*

THE effect of the war period on the construction industry has been the subject of a remarkable amount of comment. Predictions of things to come are appearing regularly in popular periodicals and the daily press, supplementing the more sober and conservative discussions of technical writers. While many of the more extreme ideas promoted may never come to pass, it is safe to say that some new developments will find their places among the old and accepted standard practices. These new developments for the most part will actually represent the use of existing materials and methods for other purposes and in other ways than before.

With the advent of the war, civilian construction came to almost a complete standstill and the fabricators of structural steel turned to war production. Much of the experience gained in war activities can now be successfully applied in the normal peacetime activities of the structural steel industry.

The housing shortage and the demand for housing for veterans and their families, the shortage of business space, and the desire of manufacturing companies to expand their facilities for peacetime development and production are the basis for predictions that the construction industry will encounter a big demand for its services. To make fullest use of the newer fabricating methods and materials in this construction it will be necessary to review and revise the building codes of municipalities and other governing bodies.

For the purpose of determining the nature of building codes throughout the United States a survey of 205 cities having a population of 50,000 or more was conducted. While this survey was undertaken primarily to determine what provisions are made for the use of welding, and to apprise building officials of the 1946 edition of the AMERICAN WELDING SOCIETY'S "*Standard Code for Arc and Gas Welding in Building Construction*," the replies received, representing a good cross section of municipalities as to size and type, are interesting for other information as well.

Since the nature and amount of construction and the facilities and personnel necessary for the administration of building code requirements vary according to the size of a city, the replies received have been classified in one of four groups according to the size of the city by population. The replies received have been tabulated on this basis in Table 1. The same basis is used in the analysis of all other data.

A building code may be regarded as a compilation of good structural practices as of the time of its issuance. It is evident therefore that in a period of much new development a code may become out of date and hence restrictive soon after its issuance.

Analysis of the replies received shows that building codes presently in effect range in age from 42 years (1904) to two or three months (1946). The range of age is about as wide in one group as it is in any other.

Table 1—Summary of Replies Received

Population	Number of Questionnaires Mailed	Replies Received	Replies Received, %
500,000 and over	16	11	69
250,000 to 500,000	22	19	86
100,000 to 250,000	60	43	72
50,000 to 100,000	107	67	63
Total	205	140	68

Since the task of preparing revisions to a building code is often long and costly, it is not likely to be undertaken too often for individual cities. To offset this difficulty several means have been adopted for introducing new developments without revising the code.

Earlier building codes generally provided rather hard and precise regulations on each aspect of construction. The more recent tendency, however, has been to specify general requirements which will assure a safe minimum of good design and workmanship and to supplement code requirements by rules, interpretations and any other regulations which may be necessary. These regulations are not incorporated into the administrative law and may be changed more readily.

In some instances provision is made in a code for the use of any method or material which is proved to the satisfaction of the building official. In other instances, especially in the large cities, the use of new methods and materials is permitted under special permission, granted on appeal, by the building official. Other procedures for approval are essentially variations of the above according to some particular requirements of a city or according to the particular ideas of the building official. In any case these procedures are all unsatisfactory for extended use and unless periodic recognition is formally given to new methods and materials, the building code will soon come to be ignored. (Several building officials indicated in their replies that they did in fact ignore their cities' building codes because they were too old.) Further, where special permission must be obtained, often such permission must be requested for each separate instance, thereby adding to the cost of the construction contemplated and the municipal administration thereof. It would seem, therefore that ideally building code requirements should be reviewed and revised frequently and kept up to date.

The building officials themselves have recognized this and have joined together in such nation-wide or regional organizations as the Pacific Coast Building Officials' Conference, The Southern Building Codes Congress and the Building Officials' Conference of America.

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These organizations prepare a standard uniform building code which in turn may be adopted by all municipalities. The cost of preparing revisions, which are issued at regular intervals, is thus shared by the many members of each organization. This procedure has the further advantage of providing uniform requirements in many municipalities, which is advantageous to the fabricators, constructors and suppliers of materials as well as to the cities themselves. With periodic revisions at frequent intervals it is possible to provide for new developments almost as soon as they have been deemed satisfactory for general adoption.

That we have encountered many new developments and that there is need for administering their use in building construction is clearly reflected in the replies of the building officials to our questionnaire. Eighty-four, or 60%, of those replying, indicated that a revision of their building code was contemplated. Of those not contemplating revision, eighteen had adopted revisions in 1945 or 1946 and several others indicated that revision was not being undertaken because of a lack of funds. (It is interesting to note here that four of the cities have no code at all, but rely on "good practice" as based on recommendations of recognized organizations.) A detailed breakdown of the number of cities in each group contemplating revision is shown in Table 2. This table shows that a greater percentage of larger cities are contemplating revisions; this may be due to the availability of more funds and a larger staff.

Table 2—Cities Contemplating Revision of Their Building Codes

Population	Total Number of Replies Received	Revision Contemplated or in Progress Yes	No	Percent Contemplating Revisions
500,000 and over	11	8	3	73
250,000 to 500,000	19	13	6	68
100,000 to 250,000	43	25	18	58
50,000 to 100,000	67	38	29	57
Total	140	84	56	60

All of the foregoing has been general and is of interest where any new development or material is concerned. While the use of welding in building construction is not new by any means, it is only in recent years that it is receiving proper acceptance, and provisions are being made for its use without undue restrictions. There is much to be accomplished yet in this regard, and many building officials permit the use of welding only after some special tests are made or a special permit is obtained.

Of the 140 replies received, 113, or 80%, indicated that welding was permitted as a means of fabricating structural steel. However, the provisions vary considerably, with many of the cities requiring special permission of the building department.

The AMERICAN WELDING SOCIETY through its Committee on Building Codes has endeavored to provide proper requirements for the use of welding in building construction and has issued a welding code for building construction which is revised from time to time. A 1946 "*Standard Code for Arc and Gas Welding in Building Construction*" has only recently been issued to supersede the 1941 tentative edition. The design requirements including allowable unit stresses, workmanship requirements, inspection and operator qualification requirements have all been formulated on the basis of research and testing as well as the actual experience of the structural engineers comprising the Committee. It is intended that the provisions embodied in the Code be adopted by municipalities and other code-writing bodies either by citation or by actual inclusion of the provisions of the A.W.S. Code, and the Committee has assisted many building officials in the formulation of their welding requirements on this basis.

As a result of these activities, the A.W.S. Building Code forms the basis of a very large majority of the welding provisions governing the application of welding in the fabrication and erection of structural steel.

Table 3 shows a list of cities permitting welding under regulations generally conforming to the provisions of

Table 3—Cities Permitting Welding Under Regulations Generally Conforming to the A.W.S. "*Code for Arc and Gas Welding in Building Construction*"*

A. Population of 500,000 and Over

Baltimore, Md.	Detroit, Mich.
Boston, Mass.	Hartford, Conn.
Buffalo, N. Y.	Milwaukee, Wis.
Chicago, Ill.	St. Louis, Mo.
Los Angeles, Calif.	

B. Population of 250,000 to 500,000

Atlanta, Ga.	Indianapolis, Ind.
Birmingham, Ala. (1937)	Kansas City, Mo.
Cincinnati, Ohio (1934)	Minneapolis, Minn. (1937)
Columbus, Ohio	Portland, Ore. (1934)
Dallas, Tex. (1921)	Rochester, N. Y.
Denver, Colo. (1934)	St. Paul, Minn.
Houston, Tex. (1937)	Seattle, Wash. (1934)
Toledo, Ohio	

C. Population of 100,000 to 250,000

Cambridge, Mass. (1934)	New Bedford, Mass.
Charlotte, N. C.	Norfolk, Va.
Chattanooga, Tenn. (1937)	Omaha, Neb. (1934)
Dayton, Ohio	Peoria, Ill. (1934)
Des Moines, Iowa (1937)	Phoenix, Ariz.
Erie, Pa.	Richmond, Va.
Evansville, Ind. (?)	Sacramento, Calif. (1937)
Flint, Mich.	Salt Lake City, Utah
Fort Wayne, Ind.	San Diego, Calif. (1928)
Gary, Ind.	Scranton, Pa. (1934)
Jacksonville, Fla.	South Bend, Ind.
Kansas City, Kan.	Springfield, Mass. (1937)
Knoxville, Tenn. (1937)	Tacoma, Wash.
Long Beach, Calif.	Trenton, N. J.
Miami, Fla. (1937)	Wichita, Kan. (1937)
Nashville, Tenn. (1937)	Wilmington, Del.
Youngstown, Ohio (1937)	

D. Population of 50,000 to 100,000

Allentown, Pa.	Jackson, Miss. (1937)
Amarillo, Tex. (1937)	Kalamazoo, Mich.
Atlantic City, N. J.	Lincoln, Neb. (1921)
Austin, Tex. (?)	Madison, Wis.
Berkeley, Calif.	Newton, Mass.
Cedar Rapids, Iowa (1937)	Oak Park, Ill.
Charleston, W. Va.	Passaic, N. J.
Cheyenne, Wyo.	Portland, Me.
Corpus Christie, Tex.	Pueblo, Colo. (1937)
Durham, N. C.	Racine, Wis.
East Orange, N. J.	Rock Island, Ill. (1937)
El Paso, Tex.	Saginaw, Mich.
Fargo, N. D.	Santa Monica, Calif.
Fresno, Calif.	Sioux City, Iowa (1937)
Galveston, Tex.	Sioux Falls, S. D.
Glendale, Calif.	Springfield, Ohio
Greensboro, N. C.	Stockton, Calif.
Hamilton, Ohio	Terre Haute, Ind.
Hammond, Ind. (1938)	Topeka, Kan. (1937)
Hamtrack, Mich.	Wheeling, W. Va.
Highland Park, Mich.	Winston Salem, N. C. (1937)
Irvington, N. J.	Waterloo, Iowa
Wilkes Barre, Pa.	

NOTE: This table should be used only as a guide. For the exact requirements of any city consult its building code and regulations.

* This table lists only information received in reply to questionnaire and does not include other cities, such as New York and Pittsburgh which may use the AWS Code, from which replies were not received.

the 1941 edition of the "Code for Arc and Gas Welding in Building Construction." In some instances, primarily because of the age of the building code, earlier editions of the A.W.S. Code are cited; this is shown parenthetically in Table 3. Since the 1946 edition has been published only recently, its provisions are in force only in those cities where the "most recent edition" is cited in the Code.

Table 3 should not be used to determine the welding requirements of a given city without further reference. In many cases special requirements are imposed, such as lower unit stresses, special permits and special operator qualification tests. Therefore anyone interested in employing welding for structural steel construction should consult the code requirements of the city in which the structure is to be erected.

Referring again to Table 3, of the cities not listed in Group A, Oakland and San Francisco, Calif., have replied indicating that revision of their codes is now under way. Further, from other information it is known that revisions are now being prepared for the cities of Cleveland, New York, Philadelphia and Pittsburgh. All of the cities listed in Group B, which make reference to earlier editions of the A.W.S. Code, also have indicated in their replies that revision of their building codes is contemplated. Of the four cities not listed Jersey City, N. J., Memphis, Tenn., and Providence, R. I., have indicated that revisions of their building codes are contemplated to include provisions for welding. The City of San Antonio, Texas, has no building code and welding is permitted by special permission.

All of the cities listed in Group C, as using provisions from earlier editions of the A.W.S. Code, have also indicated that revision of their building codes is contemplated, with the exception of Des Moines, Iowa, Knoxville, Tenn., Peoria, Ill., and Sacramento, Calif. Further, of the cities not listed, five—including Akron, Ohio, Bridgeport, Conn., Fall River and Lowell, Mass., and Oklahoma City, Okla.—have indicated that revision of their building code is contemplated to include provisions for welding. In addition the City of Spokane, Wash., permits welding under its own provisions and the City of Canton, Ohio, which has no building code, permits welding on the basis of good practice.

In Group D, all of the cities listed as using provisions from the earlier editions of the A.W.S. Code also have indicated in their replies that revision of their building codes is comtemplated to bring them up to date, with the exception of three cities: Hammond, Ind., Pueblo, Colo., and Sioux City, Iowa. Further, of the cities not listed, Lansing, Mich., Macon, Ga., Niagara Falls, N. Y., Portsmouth, Va., Rockford, Ill., and St. Joseph, Mo., have indicated that they use their own provisions and all but Rockford are contemplating revisions. Of the other cities replying, nine have indicated that revisions of their codes are contemplated to include welding provisions, which their present codes do not include. They are: Brookline, Mass., Columbia, S. C., East Chicago, Ind., Evanston, Ill., Harrisburg, Pa., Lawrence and Lynn, Mass., Pontiac, Mich., and Roanoke, Va. The cities of Lancaster and York, Pa., have no building codes and the remaining cities replying do not permit welding and are not contemplating revisions of their code to permit welding.

In many instances, the cities listed in Table 3 have adopted the welding provisions of the A.W.S. Building Code through adoption of a standard state or national building code. This procedure is in accordance with the previously mentioned method of keeping building code provisions up to date. Since most of these standard codes are revised regularly at intervals of two or three years, it can be expected that the 1946 "*Standard Code for Arc and Gas Welding in Building Construction*" will be the basis of welding requirements for a majority of the municipal building codes within about three years.

Some of the standard state and national building codes and the organizations under which they are prepared are listed in Table 4. Allowable design unit stresses are generally treated separately in these codes, hence are shown in a separate column in Table 4.

Building code requirements can be kept up-to-date only through the cooperative effort of building officials, structural engineers, material engineers and others interested in structural fabrication. Where sound, but not restrictive, welding provisions have been adopted it is as a result of such cooperation. In very many of the instances Local Sections of the AMERICAN WELDING SOCIETY have organized committees who, together with

Table 4—Welding Provisions of Basic Building Codes

Code	Welding Provisions: Allowable Design Unit Stresses	Welding Provisions: Workmanship, Inspection and Operator Qualification
Uniform Building Code (Pacific Coast Building Officials Conference)		
1946 Edition*	1941 A.W.S. Code	1941 A.W.S. Code (Cited)
1941 Edition	1937 A.W.S. Code	1941 A.W.S. Code (Cited)
Southern Standard Building Code (Southern Building Code Congress), 1946 Edition*	1941 A.W.S. Code	1941 A.W.S. Code (Cited)
Suburban Building Officials Conference Code	A.I.S.C. Specifications†	A.I.S.C. Specifications†
National Board of Fire Underwriters Building Code, 1943 Edition	1941 A.W.S. Code	1941 A.W.S. Code (Cited)
Building Code Requirements for Structural Steel (Riveted, Bolted or Welded Construction), (American Standards Association), 1943 Edition	1941 A.W.S. Code	1941 A.W.S. Code (Cited)
Specification for the Design, Fabrication and Erection of Structural Steel for Buildings (American Institute of Steel Construction)		
1946 Edition	1946 A.W.S. Code	1946 A.W.S. Code
1942 Edition	1941 A.W.S. Code	1941 A.W.S. Code
Wisconsin State Building Code. 1942 edition with 1945 amendments	1941 A.W.S. Code	Own Provisions Based on 1941 A.W.S. Code with A. W. S. Operator Qualification Tests cited
Building Rules and Regulations (Administrative Building Council of Indiana) 1945 edition	1941 A.W.S. Code	1941 A.W.S. Code (Cited)
Building Code of the Connecticut State Housing Authority (new edition in preparation)	Most Recent A.W.S. Code	Most Recent A.W.S. Code

* Adopted prior to issuance of 1946 A.W.S. Code.
† Conforms to 1946 A.W.S. Code.

similar groups from other engineering societies and local representatives of the American Institute of Steel Construction, have cooperated with the building departments. Such activities are presently under way in the cities of Philadelphia, Cleveland, New York, Los Angeles and Minneapolis, to cite a few. These local committees are comprised of men engaged in structural steel construction who have, in addition to their practical experience, the advantage of familiarity with local conditions and the particular needs of these conditions.

The technical staff of the AMERICAN WELDING SOCIETY and the membership of the Committee on Building Codes will be pleased to assist any such local committees in their activities. It is only through the cooperative effort of all that welding will be used soundly and most effectively in the structural steel industry.

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(*Continued on page 239*)

Radiography and the Fatigue Strength of Spot Welds in Aluminum Alloys*

By R. C. McMaster and H. J. Grover†

Introduction

THE usefulness of spot-weld radiography in predicting static shear strength and in revealing defects in spot welds in aluminum alloys has been illustrated in several recent papers.[1–4] In another paper,[5] the fatigue properties of spot welds have been indicated by the results of extensive tests in which several variables of weld spacing were investigated. It is natural that inquiry should now be made into the possibilities of correlating the indications of radiographic inspection with the fatigue strength of spot welds.

It is unfortunate that, in many cases, extensive fatigue tests have been made on spot welds whose properties were not determined in advance by means of radiography. And in many other cases, the spot welds used for fatigue tests were normal production spot welds made under standard industrial conditions, without the purposeful introduction of defects or controlled variations in significant weld properties. As a result, these fatigue tests provide little fundamental information on the influence of weld defects upon fatigue strength, nor do they explain clearly what intrinsic weld properties determine the fatigue strength. Yet such data would be very useful in the design of structures for spot welding, in the control of welding operations and in the inspection of spot-welded assemblies.

During the war period, several West Coast aircraft manufacturers cooperated in making available a large number of production spot-weld specimens in which significant variables were controlled and specific welding conditions were varied through a wide range of operating conditions. These spot welds were radiographed in preparation for fatigue tests. Unfortunately, only a small group of these welds could be fatigue tested prior to the end of the contract authorizing the research. The results were of sufficient interest, however, to indicate the promising possibilities of such an investigation. They are summarized in this paper for the use of aircraft designers and spot-weld engineers, and with the hope that a more complete investigation of the tentative conclusions may be made in the near future.

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Experimental Work

Welding of Specimens

The 137 spot welds of this test group were made under carefully controlled production conditions in the spot-welding department of a large aircraft factory. A two-layer combination of 0.040-in. thickness sheets of 24S-T Alclad aluminum alloy was selected for the tests, since it represented a sheet material and gage very commonly spot welded in aircraft production. The welds were made on a high-capacity condenser discharge type spot welder which had been certified for a wide range of sheet materials and gage combinations. The welds were placed 1 in. apart in shear test panels with 1-in. overlap. Fifteen similar welds were made at each of nine different welding energy levels. These varied from low energy settings producing small welds through the normal energy range to high energy settings producing oversize and defective weld nuggets. The sheet indentation was kept within reasonable limits through the use of large tip radii on the welding electrodes.

Table 1—Data on Sheet Preparation and Welding of Fatigue Test Specimens

Material.....	0.040 to 0.040-in. 24S-T Alclad
Machine.....	Taylor-Winfield Hi-Wave, condenser discharge welder, 440 line volts
Electrode pressure.....	1100 lb. (constant)
Capacitance..	960 mfd. (constant)
Voltage.....	1350–2250 v. (variable)
Throat.....	31 in. (constant)
Arm.....	9½ in. (constant)
Radius top electrode...	4 in. (constant)
Radius bottom electrode.	4 in. (constant)

Material cleaned in Oakite No. 63 and Oakite No. 84A

Panel No.	D.-C. Voltage	Weld Nos.
1	1350	1–15
2	1500	16–32
3	1600	33–47
4	1700	48–62
5	1800	63–77
6	1925	78–92
7	2025	93–107
8	2125	108–122
9	2250	123–137

Table 1 summarizes the welding conditions.

Radiographic Inspection of Specimens

The welds were radiographed in a commercial laboratory which used a 150-kvp. rectified X-ray source. Exposures were made at approximately 35 kvp. (the glass envelope of the X-ray tube and its plastic housing had significant inherent filtration). Exposure times were 800 sec. with a constant 7-milliamp. tube current. Fourteen welds were exposed simultaneously at a 36-in. source-object-distance. Three layers of Eastman Type M X-ray film were exposed simultaneously, being wrapped only in opaque photographic paper with lead backing to prevent back scatter. Contact reproductions of radiographs of typical welds in this group are presented in Fig. 1.

The spot-weld radiographs were examined and measured, and the inner and outer diameters of the radiographic dark ring (corresponding to the inner boundary of the Alclad inclusion and the outer boundary of the weld nugget, respectively), the diameter of the corona ring and the extent of defects such as undersize weld nuggets, cracking, porosity, expulsion, extrusion, misshapen nuggets, excessive Alclad inclusion, segregation of eutectic in the parent material and oversize nuggets were listed. Typical inspection data are given in Table 2, where weld defects are classified numerically in accordance with the spot-weld defect classification charts given in the preceding paper of this series.[4] Save for the welds purposely made with inadequate or excessive welding energies, these welds were reasonably free from defects and represented good industrial welding practice.

Fatigue Tests of Specimens

The spot-weld specimens were subjected to tension fatigue tests on Krouse axial loading fatigue testing machines at Battelle Memorial Institute. These testing machines, rated at 4000 lb. maximum load, applied pulsating tension loads to the specimens. The ratio of minimum to maximum load was fixed at +0.25 for all specimens (no reversal of load occurred). The fatigue-test specimens, consisting of panels 3 in. wide containing three spot welds, were loaded so that the spot welds were in shear. Four similar fatigue specimens were available from each welder energy setting, being tested to failure in fatigue under successively higher values of maxi-

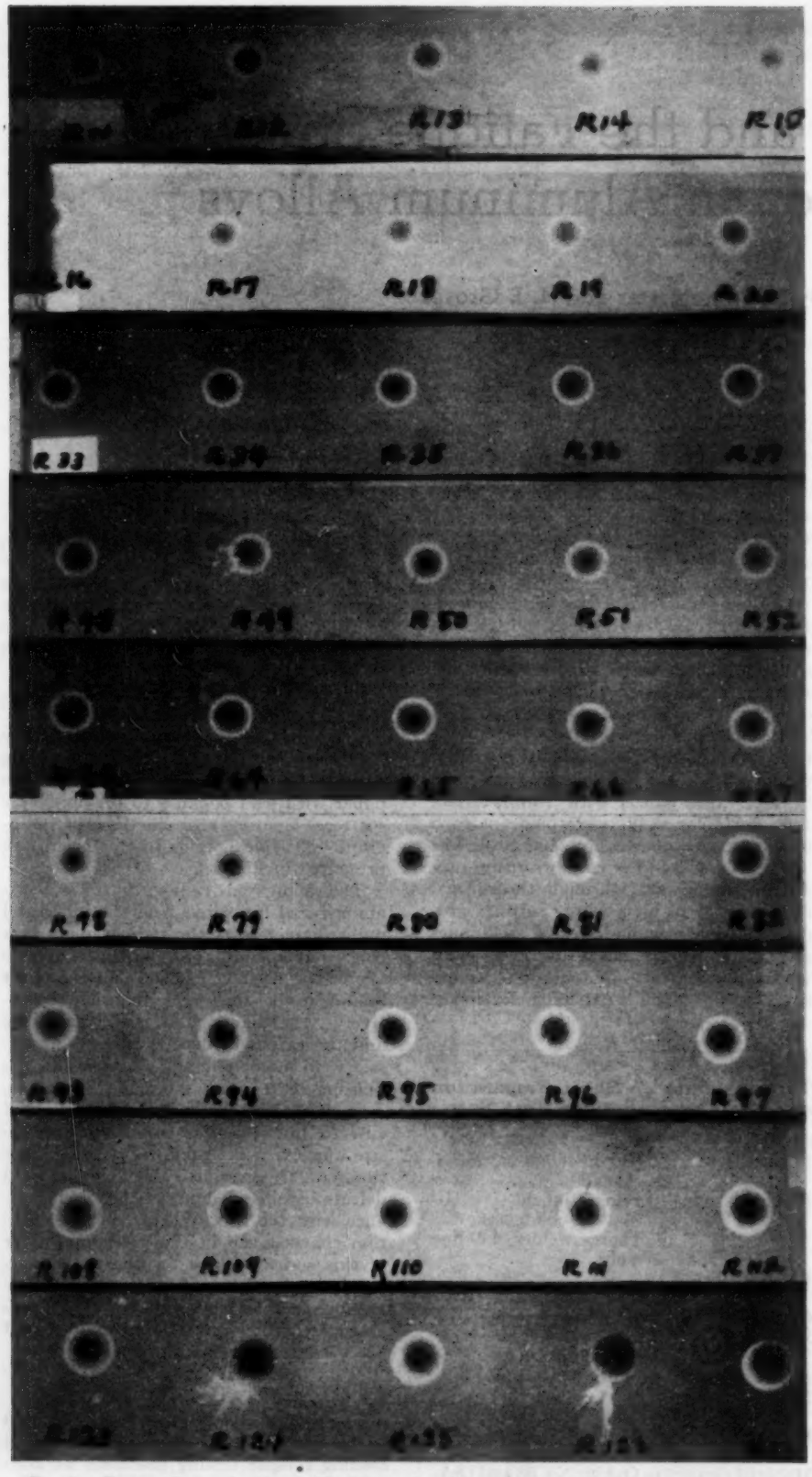


Fig. 1—Contact Reproductions of Radiographs of Typical Spot-Weld Fatigue Specimens

mum load. The results of these tests are summarized in Table 3.

Single-spot shear test specimens from each welder energy setting were subjected to static shear tests for comparison with the fatigue tests, with the results listed in Table 4.

The results of these tests are plotted in the form of stress-cycle (S-N) curves in Fig. 2. The static strengths are shown as points for comparison with the fatigue strengths.

Interesting comparisons may be made between the static and fatigue strengths of these welds. In general, both strengths were increased by increases in nugget size and in outer diameter of the corona ring which accompanied increased welding energy. However, the increase in fatigue strength was far less, proportionally, than the increase in static strength, particularly for the longer lifetimes. The larger the nugget diameter, the smaller the ratio of the fatigue strength at long lifetimes to the static strength. For the largest welds, the fatigue strengths at 10^8 cycles were less than 20% of the static strengths. For the smaller welds, the ratio approached 50%.

The scatter in fatigue strengths was less, in these specimens, than the scatter in static strengths, particularly at long lifetimes. This is reasonable, since the long-lifetime fatigue strength, for example, appeared to depend upon the corona boundary, which remained rather uniform in shape and size.

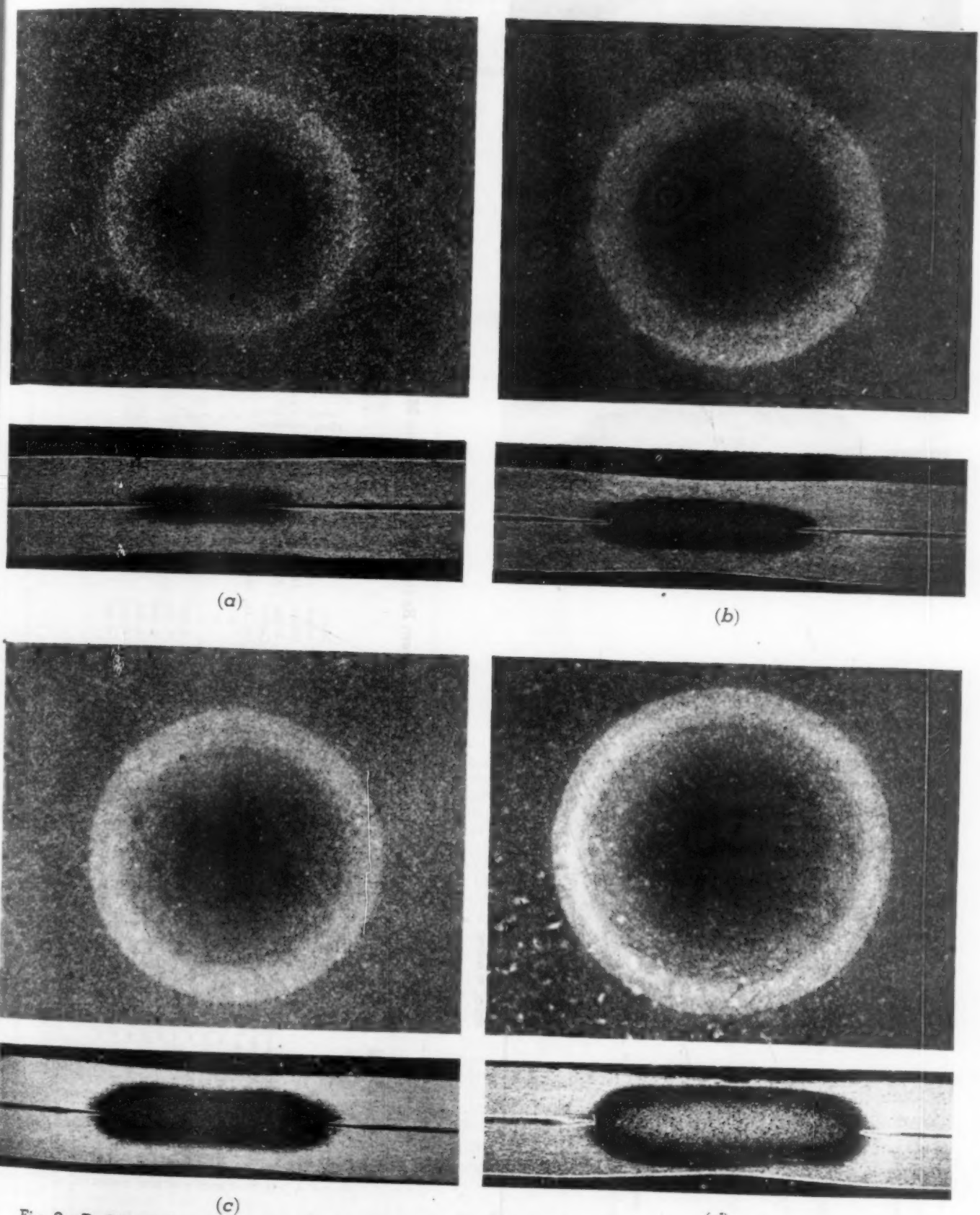
In comparing the static and fatigue strength data given in this paper, it should be remembered that static strength was determined on single-spot specimens, while fatigue strength was determined on three-spot specimens. In the latter case, although loading was applied uniformly to the specimens, there is no proof that the individual spots shared the load equally. Thus the low apparent ratios of fatigue to static strength may not be entirely real.

Metallographic Examination of Specimens

All of the spot welds in the fatigue test specimens were sectioned and photographed at 10-diam. enlargement after completion of the fatigue tests. Figure 3 shows typical weld sections from each panel, together with the corresponding radiographs. (The welds chosen were from specimens in which the fatigue failure had not yet propagated to the welds shown.) The wide range of nugget sizes, and the variations in other weld properties which accompanied the increasing welding energy, are visible in these examples. Data from the macrographic examination are summarized in Table 2.

Five characteristic modes of fatigue failure were observed in these sectioned specimens, as shown in Fig. 4. The first characteristic type of failure was a shearing of the nugget at the faying plane, similar to the failures obtained in static shear tests of small nugget spot welds. The second characteristic type of failure appeared in section as a crack propagating from the inner extremity of the Alclad inclusion (protrusion) through the weld nugget and the parent material to the sheet surface. The third type appeared in section as a crack propagating from the nugget periphery at the interface along the boundary between the weld nugget and the parent alloy (in the heat-affected zone) and then through the parent material to the sheet surface. The fourth type of failure occured in welds with nugget extrusion at the faying plane, and appeared in section as a crack propagating from the interface at the extrusion through unaffected parent material to the outer sheet surface. The fifth type of failure appeared in section as a crack propagating from the outer extremity of the corona ring at the interface, through unaffected parent material to the outer sheet surface. No other modes of failure were observed in these weld sections.

The number of times each characteristic type of failure occurred in the sectioned welds is listed in the last columns of Table 3, where the column headings cor-



(a) (b) (c) (d)

Fig. 3—Radiographs and Section Macrographs of Typical Spot Welds from Test Panels Made with Successively Increasing Welding Energy

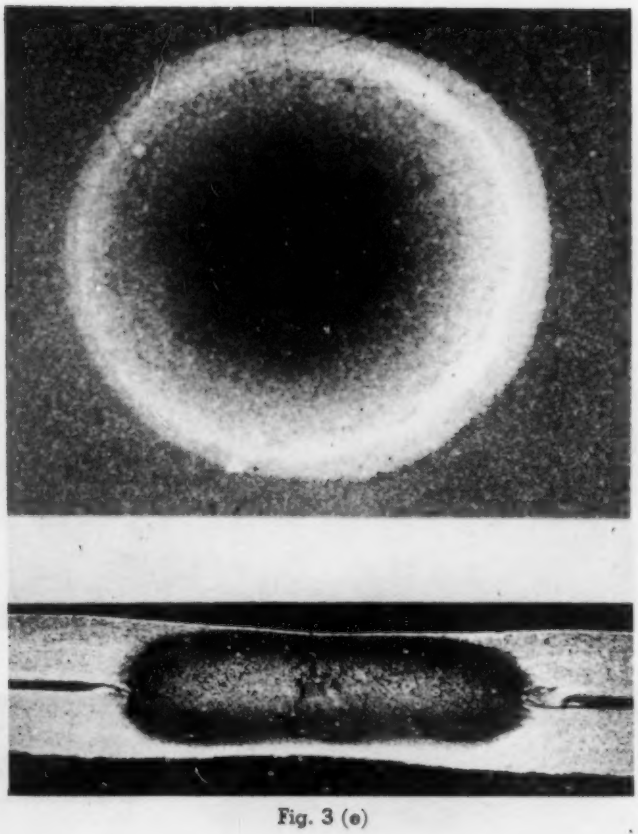


Fig. 3 (e)

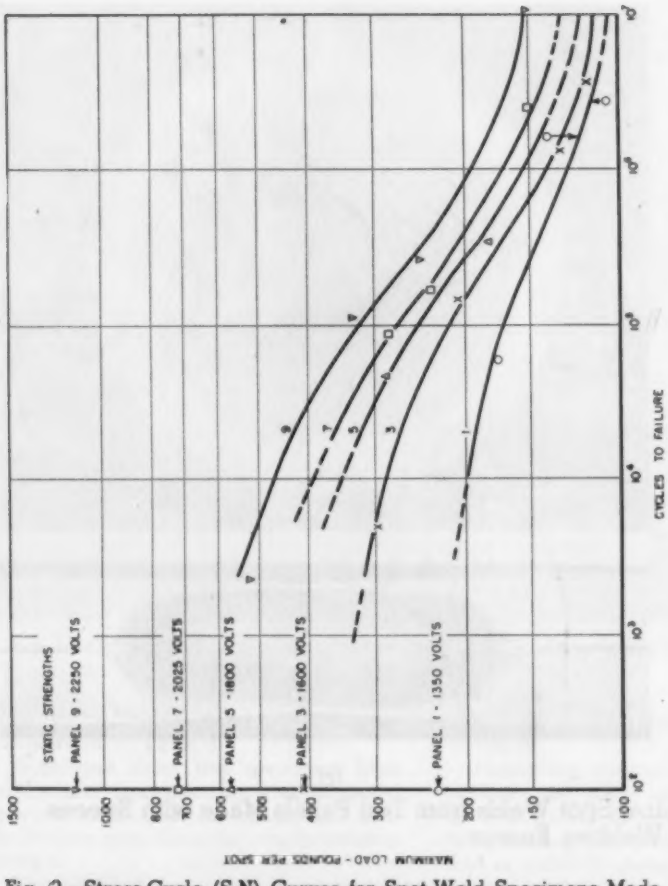

STATIC STRENGTHS
PANEL 9 - 2250 VOLTS
PANEL 7 - 2025 VOLTS
PANEL 5 - 1800 VOLTS
PANEL 3 - 1600 VOLTS
PANEL 1 - 1350 VOLTS
CYCLES TO FAILURE
MAXIMUM LOAD - POUNDS PER SPOT

Fig. 2—Stress-Cycle (S-N) Curves for Spot-Weld Specimens Made with Varying Welder Energy in 0.040–0.040-In. Alclad 24S-T Aluminum Alloy Sheet, Ratio of Minimum to Maximum Tension Load + 0.25

Table 2—Weld Properties Determined from Radiographs and Section Macrographs

Panel No.	Weld Nos.	Av. Weld-Nugget Diameter—Radiographs, In.*	Av. Weld-Nugget Diameter—Macrographs, In.†	Av. Corona-Ring Diameter‡—Radiographs, In.	Av. Corona-Ring Diameter‡—Macrographs, In.	Av. Nugget Penetration, In.	Maximum Offset from Center Line, In.	Maximum Sheet Indentation on One Side, In.	Av. Static Shear Strength, Lb./Spot§	Spot-Weld Defects Revealed on Radiographs‖ I Undersize Weld Nuggets, Class	II Oversize Weld Nuggets, Class	III Doughnut Weld Nuggets, Class	IV Misshapen Weld Nuggets, Class	V Alclad Inclusion, Class	VI Nugget Extrusion, Class	VII Nugget Cracking, Class	VIII Nugget Porosity, Class	IX Expulsion ("Spit"), Class	X Segregation of Eutectic, Class	XI Tip Pickup, Class
1	1–15	0.106 ± 0.005	0.102 ± 0.010	0.214 ± 0.001	0.225 ± 0.001	0.020 ± 0.003	0	0.004	230 ± 30	6	..	..	..	4	..	..	..	..	..	..
2	16–32	0.121 ± 0.009	0.122 ± 0.010	0.224 ± 0.010	0.236 ± 0.001	0.031 ± 0.002	0	0.005	320 ± 20	4	..	..	..	3	..	..	..	..	..	..
3	33–47	0.154 ± 0.007	0.162 ± 0.005	0.247 ± 0.010	0.249 ± 0.001	0.037 ± 0.003	0	0.006	419 ± 20	2	..	..	..	2	..	..	..	..	..	..
4	48–62	0.162 ± 0.008	0.171 ± 0.010	0.250 ± 0.010	0.259 ± 0.002	0.040 ± 0.005	0.002	0.007	490 ± 20	0	..	..	..	1	..	..	..	..	..	..
5	63–77	0.183 ± 0.004	0.193 ± 0.005	0.260 ± 0.004	0.270 ± 0.001	0.051 ± 0.005	0.003	0.007	570 ± 10	..	0	..	..	..	..	1	1–2	..	..	..
6	78–92	0.193 ± 0.005	0.202 ± 0.010	0.271 ± 0.010	0.283 ± 0.002	0.058 ± 0.005	0.004	0.007	583 ± 5	..	1	..	..	..	..	..	1–4	..	..	..
7	93–107	0.206 ± 0.004	0.220 ± 0.005	0.283 ± 0.007	0.294 ± 0.002	0.062 ± 0.008	0.005	0.008	735 ± 10	..	2	..	..	..	..	0–5	1–4	..	..	2
8	108–122	0.225 ± 0.005	0.245 ± 0.005	0.301 ± 0.010	0.312 ± 0.005	0.065 ± 0.005	0.007	0.010	963 ± 10	..	4	..	..	..	..	0–6	6–10	0–2	0–8	6
9	123–137	0.228 ± 0.016	0.248 ± 0.010	0.314 ± 0.020	0.320 ± 0.015	0.070 ± 0.005	0.007	0.012	1075 ± 40	..	6–8	..	..	..	..	..	..	..	..	..

* Inner boundary of radiographic dark ring.
† Outer boundary of nugget (corresponds to outer boundary of radiographic dark ring).
‡ Total diameter of corona ring (not a direct measurement of corona area).
§ Average of results from 3 specimens.
‖ Defects are classified numerically according to interpretation charts for spot-weld radiographs given in the preceding paper (see preceding reference).

Table 3—Fatigue Test Results for Specimens 3-In. Wide Containing Three Spot Welds Each

Sample No.	Weld Nos.	Maximum Load† Total Lb	Maximum Load† Lb./Spot	Cycles to Failure	Frequency of Occurrence of Characteristic Types of Failure, Types* 1	2	3	4	5	Remarks
1-3	9, 10, 11	522	174	59,000	3	..	..	..	..	
1-4	12, 13, 14	398	133	1,613,900	..	2	..	..	1	
1-2	6, 7, 8	318	106	2,958,000	..	1	1	..	..	
2-3	24, 25, 26	750	250	2,900	3	..	..	..	..	
2-4	27, 28, 29	570	190	130,100	..	3	1	..	..	
2-2	21, 22, 23	474	158	831,900	..	5	1	..	..	
3-3	41, 42, 43	900	300	4,800	3	..	..	..	..	
3-1	35, 36, 37	615	205	138,500	..	4	..	..	..	
3-2	38, 39, 40	393	131	1,206,200	3	..	..	..	1	
3-4	44, 45, 46	348	116	3,410,100	..	2½	..	..	..	
4-1	50, 51, 52	736	245	800	3	..	1	..	..	
4-3	56, 57, 58	735	245	46,900	Section not available					
4-2	53, 54, 55	468	156	974,400	..	1	2	..	⅔	
4-4	59, 60, 61	390	130	4,158,000	..	..	4	..	..	
5-1	65, 66, 67	846	282	44,100	..	2	5	..	..	
5-2	68, 69, 70	540	180	33,700–1,291,600	..	..	3	..	1	Machine did not cut off
5-3	71, 72, 73	339	113	9,275,100+	..	..	..	..	..	
	Reload	1200	400	3,200	2	2	2	..	..	
5-4	74, 75, 76	540	180	321,500	..	..	4	..	..	
6-1	80, 81, 82	864	288	17,200	..	3	1	..	..	Pulled weld buttons
6-2	83, 84, 85	552	184	416,000	..	..	3	..	2	
6-3	86, 87, 88	480	160	818,000	..	..	2	..	..	
6-4	89, 90, 91	408	136	2 298,600	..	..	3	..	..	
7-1	95, 96, 97	1104	368	13,100	..	2	6	..	..	
7-4	104, 105, 106	840	280	82,700	..	..	5	..	..	
7-2	98 99, 100	702	234	147,400	..	..	4	..	2	
7-3	101 102, 103	450	150	2,351,800	..	..	..	..	3½	
8-1	110, 111, 112	1428	476	5,500	..	2	4	..	..	
8-2	113, 114, 115	912	304	67,400	..	..	1	4	..	
8-3	116, 117, 118	630	210	331,100	..	..	..	3	3	
8-4	119, 120, 121	420	140	4,075,600	..	..	..	..	4	
9-1	125, 126, 127	1596	532	2,100	..	1	4	..	..	Pulled weld buttons
9-2	128, 129, 130	1014	338	102,900	..	..	2	4	..	
9-3	131, 132, 133	720	240	247,300	..	..	..	..	6	
9-4	134, 135, 136	450	150	10,238,700	..	..	..	..	..	
	Reload	1800	600	3,300	..	..	5	..	..	

* See Fig. 4 for examples of these characteristic types of failure.
† Ratio of minimum to maximum tension load on joint = + 0.25.

respond to the examples shown in Fig. 4. These results are tabulated in Table 5, as a function of weld nugget size and of lifetime to fatigue failure.

The Influence of Weld Nugget Area at the Faying Plane

Extensive tests, previously reported,[1, 3] have indicated that the static shear strength of spot welds is predicted reliably by the net area of cast-alloy nugget bonding at the faying plane. This area of nugget bonding is revealed, for aluminum alloys like 24S-T and 75S-T Alclad, by the inner boundary of the prominent dark ring on the radiographs.

Comparing the fatigue strengths of these spot welds with the area enclosed within the inner boundary of the radiographic dark ring indicates that the fatigue strength at any fixed lifetime is predicted as usefully as is the static shear strength. Figure 5 shows both the static and fatigue strengths obtained in these tests plotted as a function of the area within the radiographic dark ring. With this group of spot welds in lap joints, the fatigue strength was predicted well by radiographic indications of the nugget diameter at the faying plane.

It is interesting to note, in the examples shown, that both the static and fatigue strengths at any fixed lifetime increased with increasing nugget diameter (increasing radiographic dark-ring diameter). However, the rate of increase of static strength with increasing nugget size was much greater than the corresponding increase in fatigue strengths. Furthermore, the fatigue strengths at long lifetimes (10^6 cycles) increased far less with increasing nugget size than did the short-life fatigue strengths (10^3 to 10^4 cycles).

With high applied loads (which caused short lifetime failures) the spot welds behaved under fatigue loading very much as under static loading; failures occurred through shear of the weld nugget at the faying plane or by pulling the "weld button" through the sheet (characteristic failure types 1, 2 and 3). Hence it is reasonable that under these conditions the fatigue strength should be indicated by the same radiographic features which predict static strength. However, under low repeated loads, the long-lifetime fatigue failures of larger spot welds occurred frequently through cracking of the unaffected aluminum alloy sheet (failure types 4 and 5). With such long-lifetime failures produced by low repeated loads, the fa-

Table 4—Static Tests on Single Spot-Weld Specimens

Weld No.	Static Ultimate, Lb.	Av.	Weld Nos.	Static Ultimate, Lb.	Av.
1-1	226				
1-2	202	230 ± 30	7-94	744	735
1-15	262		7-107	726	
2-16	320	±20	8-108	972	936
			8-109	954	
3-33	390		9-123	1114	
3-34	438	419 ± 30	9-124	Spit 702	1075
3-47	430		9-137	1036	
4-48	514				
4-49	476	490	....	.....	
4-62	480				
5-63	578	570	....	.....	
5-64	562				
6-78	584	583	....	.....	
6-79	582				

§ Average of results from 3 specimens.
‖ Defects are classified numerically according to interpretation charts for spot-weld radiographs given in the preceding

tigue strength showed little dependence upon the radiographic indications of weld nugget diameter.

It is quite apparent that spot welds which meet static strength acceptance limits do not necessarily have equivalent strengths if the stress is to be repeatedly applied, as is commonly the case with aircraft. For example, the nugget diameter which provides 250 to 300 lb. static shear strength in spot welds in 0.040-in. 24S-T Alclad must be doubled in order to provide approximately this strength at 10^5 cycles (R = +0.25). The same is true at higher stress levels. Hence in sound spot welds in lap joints which are to be repeatedly subjected to high loads, there is no advantage in restricting nugget diameter or static shear strengths to low values. Both static and high-stress fatigue strengths will be improved by increasing the weld nugget size. The low-stress fatigue life will not be lowered by such a procedure.

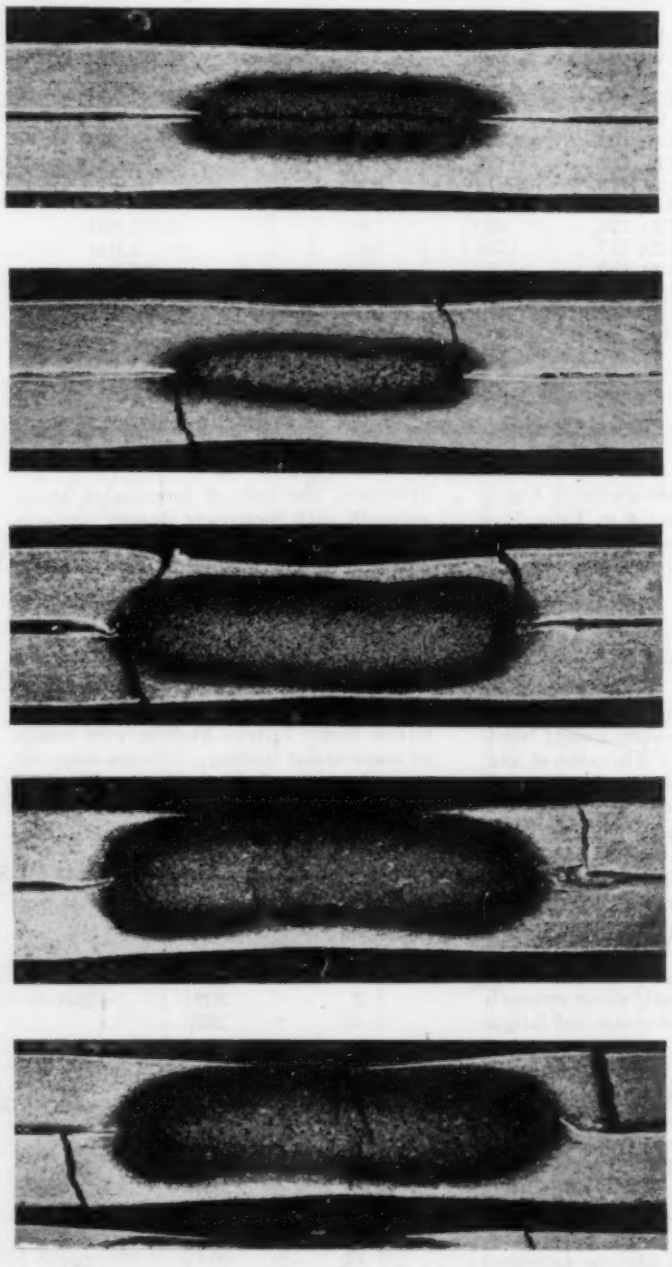
Curves of the type shown in Fig. 5 might, if the data were extended further by comprehensive fatigue tests, be used in the design of spot-welded joints for fatigue service, just as corresponding curves are now used to establish designs for static loading. Specifications for welding and inspection standards might be established for parts subject to repeated loading, and might, in general, be different from those used for parts subject to static load only.

The Influence of Corona Bonding

It is interesting to note that the load for shear failure does not approach zero as the weld nugget area decreases, in the curves of Fig. 5. Instead, the curves for all lifetimes appear to approach a common point, near 125 lb. shear strength for these weld specimens, when the nugget diameter becomes zero. This strength is contributed by the Alclad bonding at the interface, normally present in the corona region of the spot weld and, in the absence of the weld nugget, providing the entire strength of the "weld." Such "dud" spot welds, in which the nugget has not broken through the Alclad layers at the interface, can be made with areas of corona or Alclad bonding large enough to pass static shear strength acceptance tests without difficulty. The shear strength of Alclad bonding may be as high as 10,000 psi.,* in spot welds in 0.040-in. 24S-T Alclad aluminum alloy sheets. It is also possible for the bond in the corona region to have almost no strength, particularly if the welds are made in sheets with dirty or oxidized faying surfaces.

The Alclad bonding may contribute an appreciable part of the total static shear strength of spot welds in Alclad aluminum alloys. In normal spot welds, the area of Alclad bonding in the corona ring may exceed the area of cast-alloy nugget at the faying plane by a factor as large as two, in which case the corona might contribute as much to the weld strength as does the nugget itself. This contribution also influences the fatigue strength of spot welds. Figure 6 shows the faying surfaces of typical welds from these specimens, showing particularly the relatively large area of corona bonding in the welds with small nugget diameters. It is evident that the outside diameter of the corona ring does not increase in diameter so rapidly as does the nugget boundary, with increasing welding energies. Examination of the welds and radiographs indicated that the net corona area was nearly constant throughout the range of welds (0.0316 sq. in. for panel 1 to 0.320 sq. in. for panel 9). On the other hand, the weld nugget area at the faying plane increased from 0.0398 to 0.0804 sq. in.

The high-stress, short-lifetime fatigue strengths correlated well with the nugget area at the faying plane. It is probable that, in these fatigue tests just as in static tests, the corona bond tended to fail before the nugget failed, so that the ultimate failure was a function primarily of nugget size and strength. However, at the low fatigue stresses corresponding to failure at 10^6 cycles, the fatigue strengths show almost no correlation with nugget diameter. On the other hand, the increase in fatigue strengths at 10^6 cycles (about 45% between panels 1 and 9) with increasing weld energies is almost exactly proportional to the increase in the total diameter or circumference of the corona ring, which was about 43% between panels 1 and 9. It is further observed that, at these low stresses producing long lifetime, the fatigue failure occurs as a crack propagating through the welded sheets, with no evidence of failure of either the corona bond or the nugget at the faying plane (characteristic failure Type 5). Hence it appears probable that the fatigue performance of larger spot welds under low repeated stresses is primarily a function of the circumference of the well-bonded corona region.



Shear through nugget at the faying plane, usually propagating from the inner extremity of the Alclad inclusion

Crack from inner extremity of Alclad inclusion, propagating through nugget and parent alloy to the outer sheet surface

Crack starting from faying plane at nugget boundary, skirting nugget boundary and passing through parent material to the sheet surface

Crack propagating from notch at nugget extrusion at the faying plane and passing through parent alloy to the outer sheet surface

Crack propagating from stress concentration at corona boundary, and passing through parent alloy to the outer sheet surface

Fig. 4—Characteristic Types of Fatigue Fracture Observed in Spot-Welded Joints of 0.040–0.040-In. 24S-T Alclad Aluminum Alloy Sheets

* By comparison, the shear strength of the cast-alloy nugget is near 20,000 psi., while the shear strength of the unaffected parent material is above 40,000 psi.

The Influence of the Stress Concentration at the Inner Extremity of the Alclad Inclusion

Figure 5 shows, in the case of welds with Alclad inclusions, which failed by shear of the weld nugget (Type 1) or by "pulling a button" (Type 2), that failure progressed from the inner extremity of the Alclad inclusion across the nugget or through the sheet material to the outer sheet surface. After failure of the corona bond under high loads, the discontinuity at the inner extremity of the Alclad inclusion is a point of stress concentration with severe notch-like properties. It is located where the largest stress is applied by external loading of lap joints. Hence, it naturally forms a nucleus from which fatigue failures tend to propagate.

The greater the extent of the Alclad inclusion into otherwise normal spot-weld nuggets, the greater the effect of this stress concentration. Excessive Alclad inclusions not only reduce the effective area of nugget bonding, but they increase the stress at the periphery of the area of nugget bonding. The Alclad inclusions in the welds on panels 1, 2 and 3 served effectively as nuclei for fatigue failures. However, the Alclad inclusions in the welds of panels 4 through 7 were unusually small, so that fatigue failures tended to skirt the periphery of the weld nuggets, or in some cases actually started from the outer boundary of the corona ring. In the latter cases, the corona must have been very well bonded, and the point of stress concentration therefore occurred at the notch at the outer boundary of the corona region. It is obvious that good corona bonding is a desirable feature in spot welds which must carry repeated loads. Excessive Alclad inclusions are undesirable.

The Influence of Heat-Affected Zones in the Parent Material

In the case of low-energy welds, the failures tended to propagate through the weld nugget cast alloy from the inner extremity of the Alclad inclusion (types 1 and 2). However, in high-energy welds (particularly with negligible Alclad inclusions) the typical fatigue fracture skirted the periphery of the weld nugget and passed through the heat-affected zone of the parent material (Type 3). In this zone, the heat of welding has caused incipient melting along the grain boundaries and often results in segregation of eutectic. Such segregation is clearly revealed on spot-weld radiographs by light images of the deposits of copper-rich eutectic material. Such heat-affected zones in the parent material may be extended if excessive heating occurs at the electrode-sheet contact interface (particularly if the tips or sheet surfaces are dirty or oxidized). Tip pickup often occurs when such zones of incipient grain-boundary melting extend to the sheet surface. Hardness tests have indicated significant softening of the tempered parent alloy in these heat-affected regions, and it is logical to assume that the strength of the core material is significantly lowered by such heating. Hence it is natural to expect fatigue failures to propagate through these zones from nuclei at the boundary of the nugget

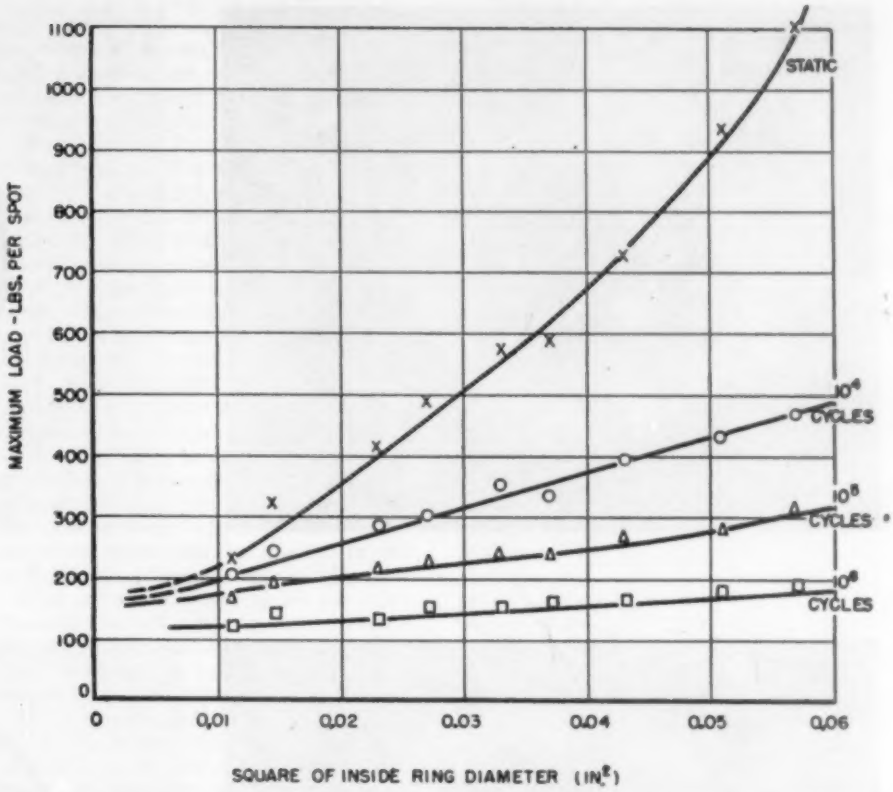


Fig. 5—Correlation Between Maximum Load for Shear Failure ($R = +0.25$) at $^1/_4$, 10^4 10^5 and 10^6 Cycles, and the Area Within the Radiographic Dark Ring for Spot Welds in 0.040–0.040-In. 24S-T Alclad Aluminum Alloy Sheets

Table 5—Frequency of Occurrence of Characteristic Types of Fatigue Failures, As a Function of Weld Nugget Size and Fatigue Lifetime

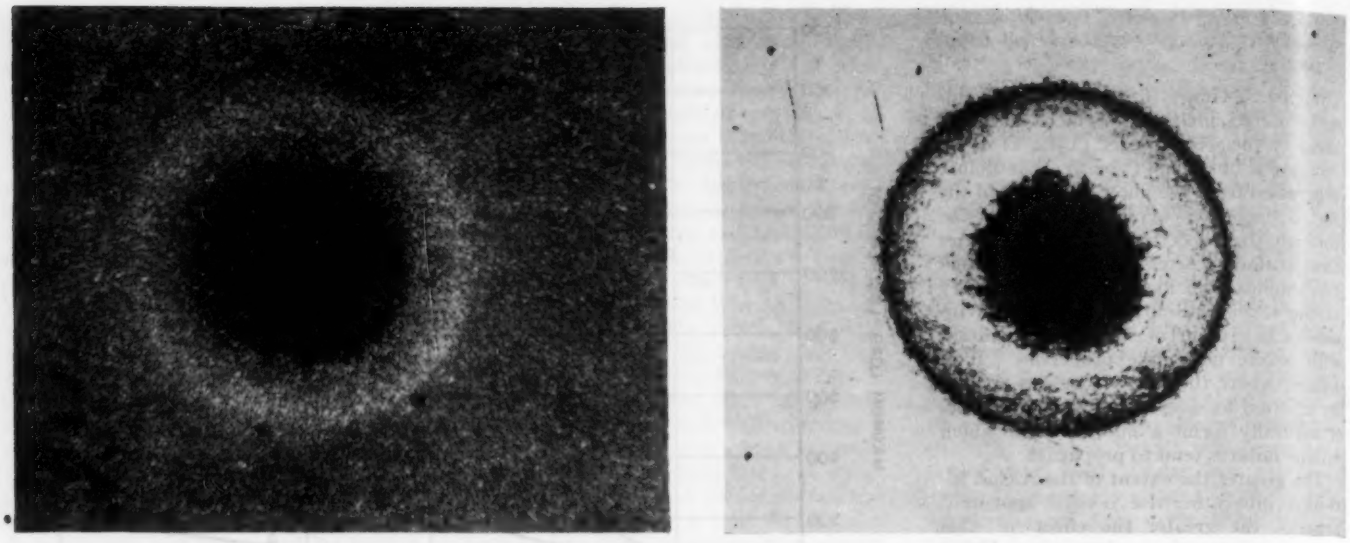
		Weld Nugget Size*															
		Very Small			Small			Normal			Large			Very Large		
Type of Failure	Life†	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
1. Shear through nugget at the faying plane		3	3	..	6	..	3	2	..	..	..	..	..	..	..	..	..
2. Crack from Alclad inclusion through nugget and parent material to sheet surface		..	3	8	..	..	$8^1/_2$	2	2	1	7	..	..	3	..	..
3. Crack propagating from interface along nugget boundary and through parent material to sheet surface		..	1	2	1	..	7	2	5	3	7	14	3	13	3	..
4. Crack propagating from nugget extrusion through parent material to sheet surface		..	..	..	..	..	..	..	..	..	..	..	..	..	11	..
5. Crack propagating from corona boundary through parent material to sheet surface		..	..	1	..	..	$^3/_4$	..	..	1	..	4	$3^1/_2$	..	9	4

* Weld nugget sizes (see Fig. 3):

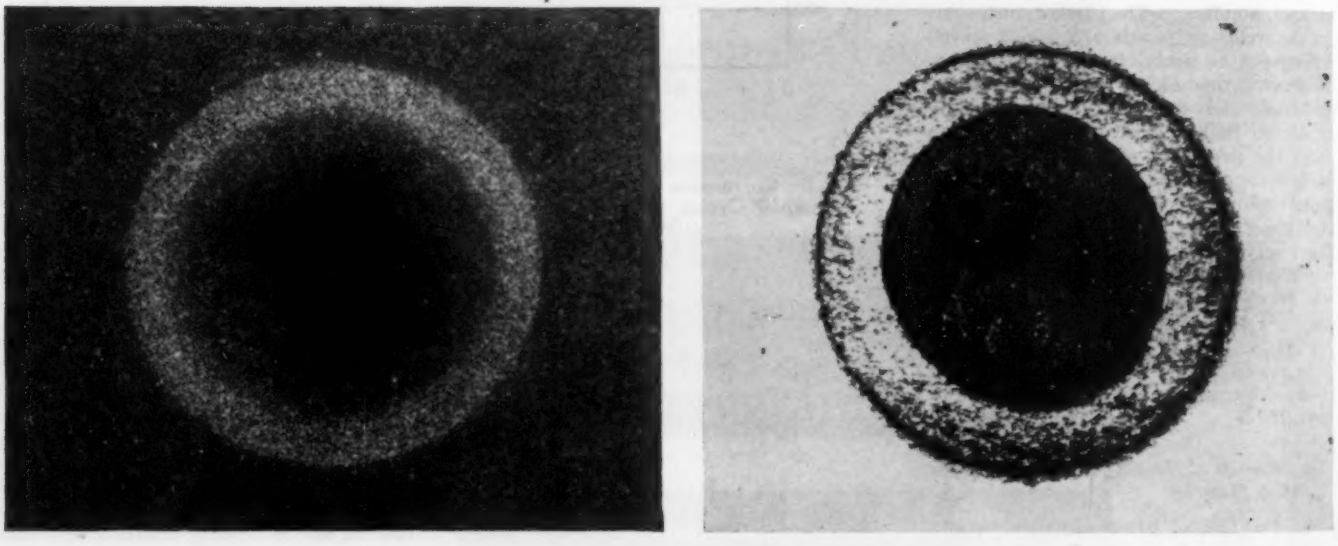
Class	Panel Nos.
Very small	1, 2
Small	3, 4
Normal	5
Large	6, 7
Very large	8, 9

† Fatigue lifetimes:

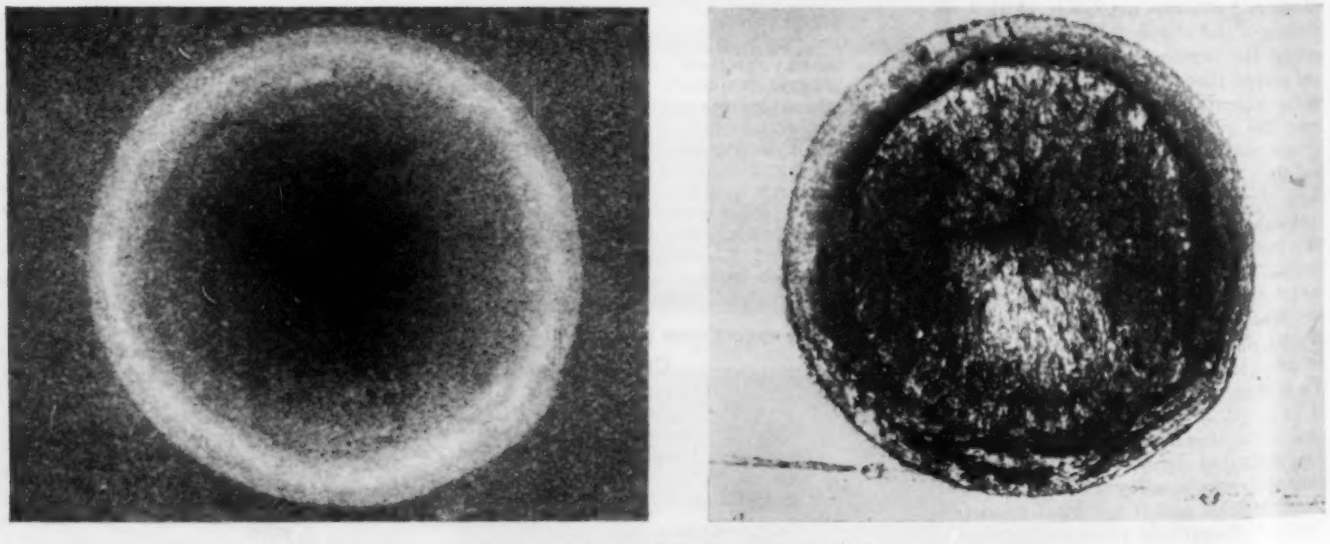
Range	Cycles
a	10^3 to 4×10^4
b	4×10^4 to 8×10^5
c	8×10^5 to 10^7



Small Weld—Panel 1, Weld 2



Normal Weld—Panel 5, Weld 64



Large Weld—Panel 8, Weld 108

Fig. 6—Radiographs and Faying Plane Macrographs of Typical Small, Normal and Large Nugget Welds, Showing Relative Areas of Nugget and Corona Bonding at the Interface. Magnification 10×

at the faying plane. Obviously, excessive heat-affected zones in the parent material are undesirable from the standpoint of fatigue strength in spot-welded joints.

Of course, it is inevitable that some of the parent material just outside the weld nugget be affected by the welding heat. Such zones are probably more extensive when the welding energy is applied relatively slowly during the formation of the weld. Hence current surges which rise rapidly to a peak and then drop rapidly to low values may be preferable to longer waves, provided no other difficulties are encountered. Furthermore, excessive nugget penetration is undesirable, since the heat-affected zone along the periphery of the nugget is thus led closer to the sheet surface, providing a more complete path of low-strength material for the fatigue fracture to follow as it propagates toward the sheet surface.

The Effect of Cracks and Porosity in the Spot-Weld Nugget

Cracks and voids in spot-weld nuggets are revealed prominently in spot-weld radiographs by dense, black images. Because of this prominence, there has been a tendency on the part of inexperienced observers to ascribe too much importance to such indications. Actually, there are no test data available as yet to show that the static shear strength of spot-weld test specimens has ever been measurably lowered by the presence of nugget cracks. Few fractures under static loading pass through the region of nugget cracks, save along the faying plane at right angles to the planes of the cracks (which are usually in planes normal to the sheet surface). Voids and porosity reduce the static shear strength only in case the nugget fails by shear along the faying plane or the fracture otherwise passes through the voids, and in such cases, the reduction in strength is usually not greater than the reduction in area along the plane of fracture.

Under fatigue loading, however, the possibility exists that nugget cracks may serve as fatigue nuclei, and cases have been observed in which cracks revealed radiographically prior to fatigue testing were extended during repeated loading and produced fatigue fractures in the welded sheets. Such a condition is not common, however, in simple lap joint specimens, for the center of the weld nugget, where the cracks most commonly occur, is a region of relatively little stress when the weld is loaded in simple shear. This type of failure may be more probable in unstressed or stressed attachments where stress flow continues through the weld region in the sheet, or in joints where a tension component of stress may be applied to the weld.

Spot welds in stiffened panels and other structures which are subject to tension and combined loadings rather than pure shear loadings, do appear sometimes to be sensitive to nugget cracking. In the case of (unstressed) scab attachments, the stress pattern through the spot weld may be an extension of the stress flow in the sheet material, and nugget cracks may have the same effect as similar cracks and stress concentrations would have were they located in the parent sheet. In addition, the weld nugget does not have the high physical strength of the unaffected parent alloy.

Several of the weld specimens contained nugget cracks (Fig. 7). These cracks had no influence upon the fatigue performance of the welded joints, since with the large welds, the fatigue failures always occurred outside the weld nugget in the parent sheet material.

In general, it appears probable that nugget cracks no more severe than classes 4 to 6 of the Weld Defect Classification Chart[4] will have relatively little influence upon the shear fatigue strength of spot welds in lap joints. Welds with small diameter nuggets will tend to fail in shear along the faying plane or fail by fracture starting at the inner extremity of the Alclad inclusion. In neither case will the influence of nugget cracks be observable in comparison with the large notch effect of the Alclad inclusion. Larger welds will tend to fail through the heat-affected parent material outside the weld nugget, or in some cases, through unaffected parent material near the corona boundary. Neither of these types of failure will be influenced by nugget cracks. The fact that the entire center of a spot-weld nugget may be drilled out without significantly influencing the shear fatigue strength of the weld[5] tends to confirm the idea that ordinary nugget cracks do not contribute to shear fatigue failures (Fig. 8).

Radiography provides a more sensitive indication of weld cracking than any other test method available, and is a useful guide in cases in which cracking does influence fatigue strength.

The Influence of Other Weld Defects

Many defects not previously mentioned in this paper are revealed in spot-weld radiographs. Nugget expulsion at the interface ("spit") certainly reduces fatigue

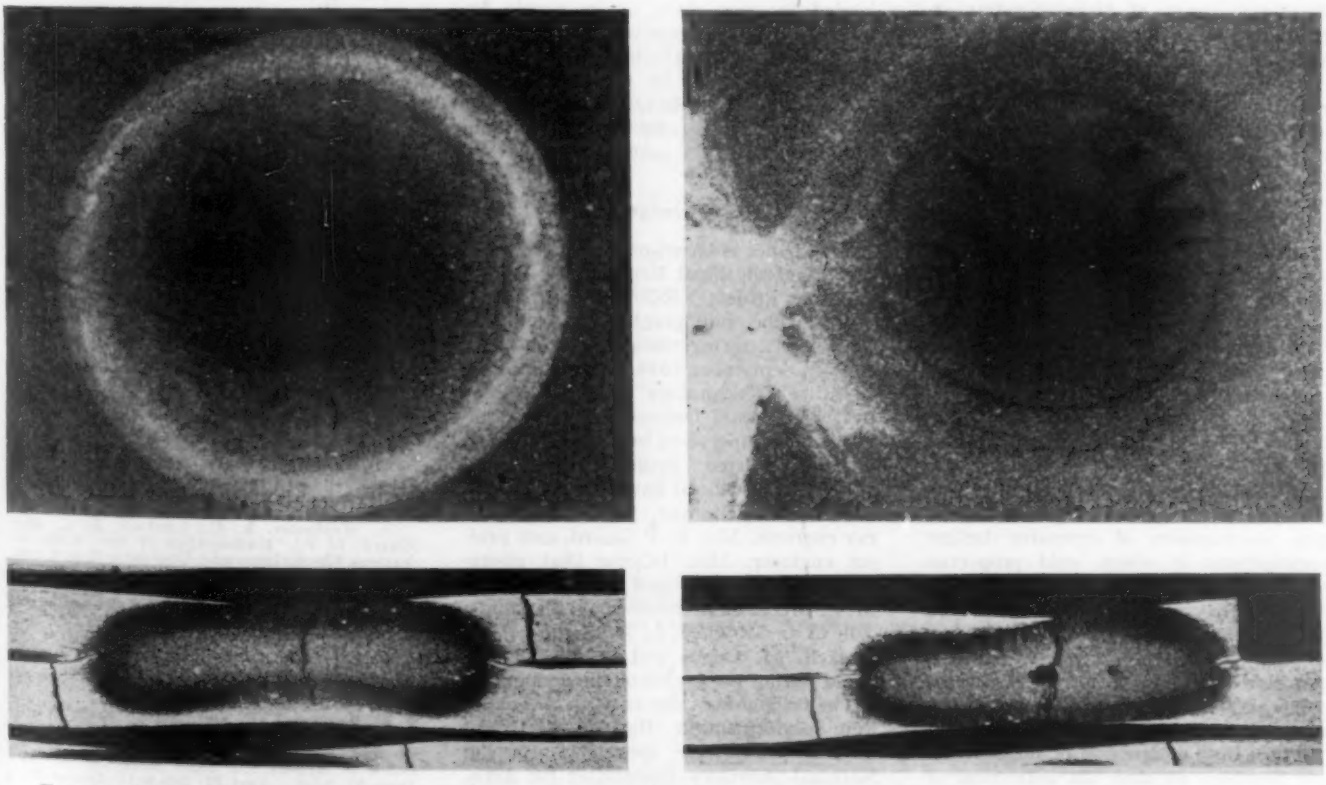


Fig. 7—Radiographs and Sections of Typical Cracked Nugget Spot Welds. In No Case Did Failure Propagate Through Such Nugget Cracks, in the Lap Joints Tested

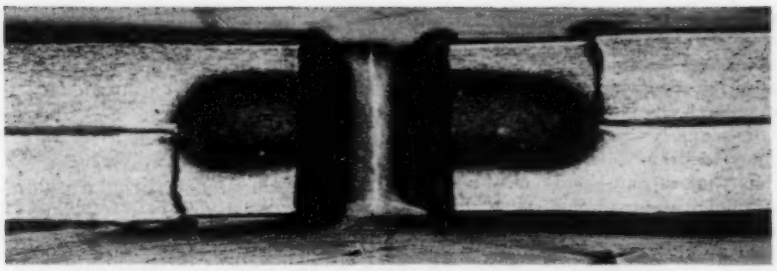


Fig. 8—Section Through a Spot Weld with a $^1/_{16}$-In. Diam. Hole Drilled Through the Nugget. Such Holes Produced No Reduction in Fatigue Strength of Spot Welds in Simple Lap Joints

strength just as it does static strength, by reducing the diameter of the nugget which is formed with a given welding energy. In addition, the expelled material may provide a wedging action under repeated loads which increases the local stress at the periphery of the weld nugget. Expulsion also prevents good corona bonding in the region of expulsion.

Nugget extrusion at the interface usually results in a notch between the extruded material and the parent sheet; with excessive extrusion, Alclad bonding in the adjacent corona region is necessarily absent. In all cases of significant extrusion in the test welds, failure of Type 4 occurred. Cracks starting from the notch at the extrusion passed through the sound parent alloy to the sheet surface. The fatigue strengths of test specimens with extruded nuggets were perhaps slightly lowered, but did not fall outside a reasonable scatter band for other welds of similar size.

Misshapen weld nuggets (doughnuts, crescents, unsymmetrical shapes) are clearly revealed on the radiographs, but their influence upon fatigue strength has not been determined. It appears probable that the effectively bonded area of cast alloy nugget and the area and diameter of the corona region of Alclad bonding are the determining factors, with shape of minor importance.

Excessive nugget penetration, nugget cracks which extend to the surface of the sheet, melting of the outer Alclad layers, tip pickup, extrusion and expulsion, and all other defects which introduce the possibility of corrosive attack on the core alloy would be objectionable when corrosion is combined with repeated stress, for under corrosive conditions, fatigue failures tend to occur at much lower stress or shorter lifetimes than in the absence of corrosion.

Conclusions

The preceding remarks and the following tentative conclusions are based on the results of preliminary tests of a relatively small number of spot-weld specimens, and upon observations of extensive fatigue investigations in which weld properties were not closely controlled or evaluated. Therefore they may be subject to revision when much more extensive studies are completed. However, the evidence is clear that radiography provides a sensitive method of evaluating weld properties which influence spot-weld fatigue strength. No other test, destructive or nondestructive, provides so clear an indication of these properties.

The static and high-stress fatigue properties of spot welds appear to be determined primarily by the size of the weld nugget at the faying plane. Larger nuggets have higher static and fatigue strengths, the increase in fatigue strengths being less, for a given increase in nugget diameter, than the corresponding increase in static strengths. The diameter of the weld nugget in 0.040–0.040-in. 24S-T Alclad must be approximately doubled in order to attain the same strength at 10^8 cycles ($R = +0.25$) as the original weld had under static loading.

The low-stress long-lifetime fatigue strengths seem to be determined frequently by the outer diameter of the corona ring, since such failures usually occur through the unaffected parent material at the periphery of the corona ring.

The Alclad inclusion into the weld nugget appears to act as a notch or stress concentrator, a nucleus from which high-stress, short-lifetime fatigue fractures propagate.

The heat-affected zone in the parent material provides a low strength path for the propagation of fatigue fractures around the periphery of the weld nugget.

Cracks in the weld nugget appear to have little influence upon spot welds loaded in pure shear as in simple lap joints, but, in the case of combined loads or of sheets with attachments where the normal stress flow in the sheet passes through the spot-weld nugget, such cracks have a damaging effect just as would similar cracks in the parent sheet.

Acknowledgments

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14. Westinghouse Electric Corp., X-Ray Division, Baltimore, Md.
15. Machlett Laboratories, Inc., Springdale, Conn.

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Choice of Cable and Transformer Size for Portable Spot Welders*

By Myron Zucker†

ALONG comes a gun-welder job in which the gun must be continually turned, twisted and pulled into awkward corners. This calls for very flexible cables—which means the smallest possible ones.

How small a cable will carry the work without overheating—and how much in terms of transformer size must be paid for the flexibility because of the higher secondary voltage required to pass the current through the smaller cable?

This is one example of circumstances where some advance figuring saves money and headaches. Such cases range from setting up standards for a complete welding department, down to choosing the cable for a single job that is so different from others that the supervisor has no experience upon which to base his choice. It is frequently wiser and more satisfactory to do a few simple computations than to go by rule of thumb carried over from past jobs, especially when low-reactance cables are being applied in a plant where single-conductor cables have customarily been used.

The purpose of this discussion is to present charts that make the selection of water-cooled cables so simple that it invites some figuring by the man on the job. After all, advance calculating simply means that the man is fitting to his own problems the accumulated experience of many people, which is the method by which American industry has achieved its tremendous production economies. Let's "cut and try" when there is no experience to go by, but think things out ahead of time when we can.

Choice of Cable Length

Cable length is one thing that is under complete control of the welding processor without much regard for cable characteristics. While it is true that best electrical efficiency is obtained with the shortest cable, it is also true that best production efficiency is often gained with cables of considerable length. In terms of flexibility, both of the cable and of the work area that can be covered with the tool at the end of it, increased length is advantageous. Before low-reactance cable was available, length *had* to be minimized because it was impractical to build transformers to provide the required welding currents. But now, for instance, 0.125-in. carbon steel can be welded with a 28-v. transformer and low-reactance cable 15 ft. long. Because of this, setups are being based more on mechanical convenience than on electrical limitations. A good viewpoint is to take a cable length that produces an economical balance between equipment cost and production rate.

* Presented at the Twenty-Seventh Annual Meeting, A.W.S., Atlantic City, N. J., week of Nov. 17, 1946.

† Vice-President, Mackworth G. Rees, Inc., Detroit 7, Mich.

Table 1—Effect of Length of Secondary Cable on Portable Spot Welder

	Short Cable	Long Cable
Electrical		
Power demand	Lower	Higher
Line-voltage drop, flicker on lights	Less	Worse
Electric power cost	Lower	Higher
Cost		
Number of welders for given coverage	More	Fewer
Cost per foot	Higher	Lower
Total cost of welder and of maintenance	Depends on job: more small welders with short cables may cost more or less than fewer units with long cables	
Mechanical		
Cable flexibility	Less	Greater
Cable weight	Less	Greater
Production rate	Depends on job	Depends on job

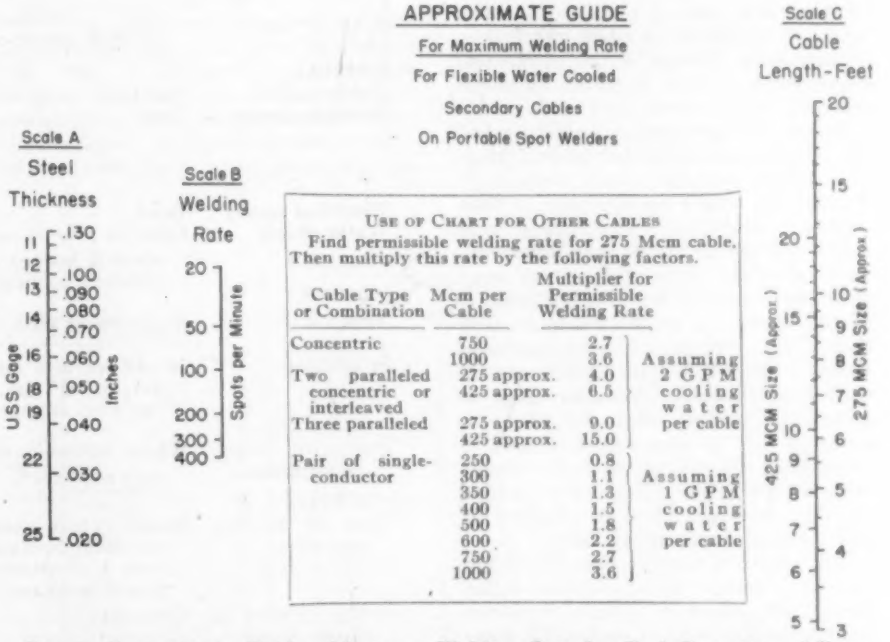

Fig. 1—Approximate Guide: Maximum Welding Rate for Cool Operation of Two Sizes of Flexible Water-Cooled Secondary Cables on Spot Welders. (275 Mcm and 425 Mcm Shown on Scale C Are Averages of Sizes Commercially Available in the Two Types of Low-Reactance Cables)

Chart based on: (*a*) One gallon per minute 60° F. cooling water per electrical side. (This can be expected with 20 psi. water pressure difference across cable when water paths are in parallel, and at about 50 psi. when paths are in series. For twice the water pressure differential the spots per minute may be increased 40%.)

(*b*) Welding energy reasonably close to A.W.S. standards for well-separated spots in clean, low-carbon steel. (Most published techniques, even the apparently widely different values of Riley and Smith's Class A, B and C Welds, are in this range. To make such welds, correct electrode pressure and size, weld spacing, line voltage, etc., are of course required.)

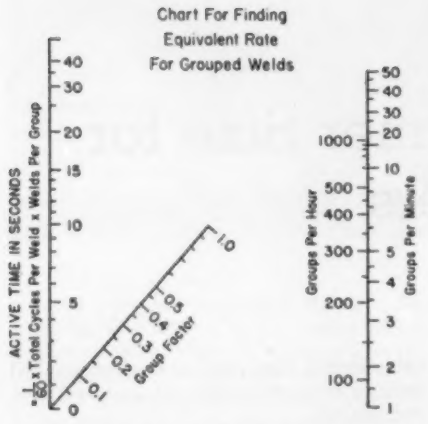

Fig. 2—Effect of Grouping Welds on Equivalent Welding Rate

Table 1 gives a check list of the effects of cable length. Many of these points are so ingrained in the minds of welding men that they are not mentioned ordinarily in such discussions. But they are definite and real, nevertheless.

Choice of Cable Type

The welding engineer takes it for granted that water-cooled cables will be used on gun welders, but he has the choice between ordinary (paired single-conductor) and two types of low-reactance cables: interleaved and concentric. Ordinary cables are practically required on push-guns (unless series welding can be used, as in Fig. 6, THE WELDING JOURNAL, October 1944, p. 915), and on certain older guns where it is difficult to adapt the low-reactance cable because of the mechanical requirements of their terminals for which the old guns were not designed.

Paired single-conductor cables should also be considered where low-current, long-time welding technique is used, particularly if cables are only a few feet long. Under these conditions, the kick does not spoil welds by throwing the gun out of position. Since small cables can be used to carry these low currents, the cable resistance is so high compared to the reactance that there is little to be gained by low-reactance cables. Single-conductor cables are in their most favorable operating range in such cases because then the relatively gentle action of the cables minimizes breakage of strands that in more common cases results in poor welds due to high electrical resistance, and to plugging of water lines and early cable failure.

Thus, the low-current short length job generally belongs to the common cable. Exceptions occur in certain multiple-point series spot welders, such as for floor-pans and door-assembly machines, where the space savings, lack of interference with adjacent cables, and uniform distribution of current between various electrodes make the low-reactance or duplex cable attractive.

The field of low-reactance cable lies in most modern clamp-guns and pinch-guns and many older ones. Just as water-cooled cables have outmoded air-cooled ones, so the points of economy, consistent welds, greater production and operator satisfaction have made low-reactance cable practically standard where mechanical considerations permit its application. These points are summarized in Table 2.

Choice of Cable Size

Large cables have some advantages (see Table 3) but usually minimum size is desired. Then the question is: "Will the small cable overheat? Let's answer this question.

Nearly the same number of active circular mils of copper are required for any commercial type of cable to prevent overheating in a given length of cable making the same weld and having corresponding water rates. But this factor is not usually important for ordinary cables, since in an attempt to overcome the "bottleneck" that their high reactance presents to the desired large secondary current, oversize cables are chosen, and they naturally run cool. Therefore, only one chart (Fig. 1) is presented for checking cable heating, and on it are shown sizes representative of the most commonly used low-reactance cables.

Values from this chart, for which the mathematical basis is given in the appendix, apply with reasonable accuracy to either interleaved or concentric design of duplex cables under conditions that result in a water flow of two gallons per minute. This is somewhat more than is usually run through the concentric type, and is the minimum recommended for the interleaved designs. The minor corrections that could be made for the difference in copper content, helix length and method of carrying water through the cable, would seldom affect the choice of cable size for a given task.

In the few cases where it is desired to check the heating of ordinary cables, the multipliers shown on the chart may be used. These factors neglect the difference between length of actual conductor in the various types of cable, and also the differentials in increase of resistance with age.

Figure 1 is similar to an accurate nomogram that has been published previously (THE WELDING JOURNAL, November 1945, p. 1026). The original chart used welding current, cable length and duty factor to establish cable size as determined by heating. This is correct and can be used for any welding conditions, provided the proper currents and duty factors are determined. It should still be used for all conditions not specifically covered by Fig. 1. But for the great majority of portable spot welding, Fig. 1 will save computations, and permit direct readings in terms

Table 2—Conditions Under Which Different Types of Flexible Gun-Welder Cables Are Favored

In a given setup, some conditions may favor single-conductor cables and others, low-reactance. For best results, all factors should be taken into account.

The underlined points generally govern the situation where they occur. Double underlined items are "musts."

	Ordinary* (Twin- single-conductor)	Low-Reactance*
GENERAL		
Cable length	Short	Long or short
Welding current	Low	Low or High (as when welding aluminum, thick steel or high-speed welding with heavy current and short time)
Electrical supply	Good	Good or adequate
Water supply	Good or poor (Costs less to replace if burned out from insufficient cooling)	Good
GUN		
Type	Single-Point Push-Gun	Clamp- and pinch-guns Series weld push-guns
Suspension	Where operator must carry full weight of gun, and cable "kick" is unimportant	Where operator is helped by steadiness of cable Where gun weight can be borne independently
Design of electrical terminals	Where movable terminals are close together	Where terminals permit application of integrated cable terminals
OPERATION		
Type of welding operation	Rough (where poor welds will not result from cable kick and from low current caused by strand breakage)	Precision (constant reactance, constant resistance, steady gun)
Depth of steel in throat of gun	Constant	Constant or variable (Current does not change so much as steel enters gun)
Prevent shutdown	Where cables can be resistance-tested and changed between production periods	Long operation—few cable changes
Flexibility	When kick is low enough so cables need not be strapped	Where kick would require strapping together single-conductor cables
Capital invested		

* Although there are differences in details of the many designs of single-conductor cables, and also between the two types of low-reactance cables on the market, the statements in this table apply in a general way to the classes as a whole.

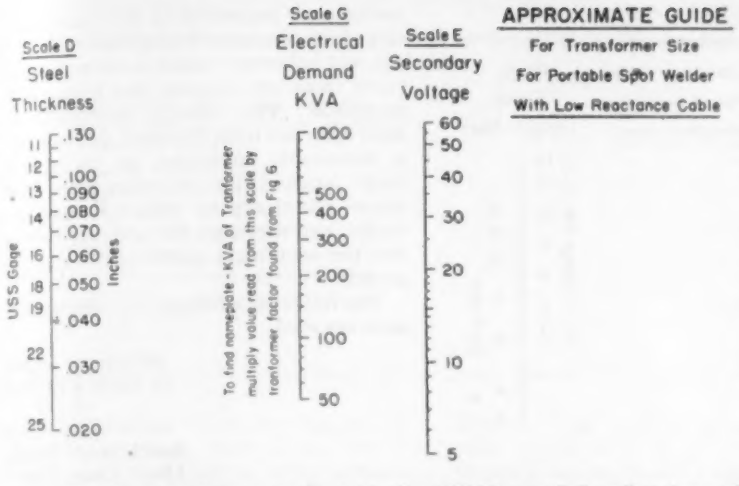

Fig. 3—Transformer for Portable Spot Welder with Low-Reactance Cable

Approximate guide to determine: (1) required open-circuit secondary voltage of transformer; (2) kva. demand during each weld for welding clean, low-carbon steel according to current recommendations of A.W.S.

Chart based on (*a*) A.W.S. or Riley-Smith Class A welding technique for direct welds; (*b*) 60-cycle power; (*c*) short connecting jumpers; (*d*) guns made of nonmagnetic material, and (*e*) larger guns with heavier cables (which accounts for higher voltages required with short lengths of 425 mcm. cable than for 275 mcm.)

familiar to maintenance and production men: that is, steel thickness and welding rate.

Suppose, for instance, that 0.040-in. sheet steel is to be welded at 150 spots per minute, with a gun at the end of a 6-ft. cable. What size cable is required for cool operation? A straight line drawn on Fig. 1 between 0.040-in. on Scale A and 6-ft. 275 Mcm on Scale C shows by its intersection on Scale B that such a cable is good for 220 spots per minute. Therefore, this cable will easily handle the anticipated 150 spots per minute.

The 400-Mcm ordinary cables that would probably be used for the same work would have even more margin as far as cooling is concerned.

Meaning of "Welding Rate"

One of the factors shown on the chart is "spots per minute," and its interpretation can have a great deal to do with getting correct results. Those who wish to consider that welding speed is simply the number of spots in the most active minute of production may do so and skip the following few paragraphs. Such procedure will yield the right answer when welds are made continuously for about a minute and will sometimes be reasonably correct even when there are several rests per minute while the tool or work is being moved.

Since there may easily be a difference of two to one in the permissible welding speed shown by this method of averaging and another easy method, the latter is given here so that borderline cases can be checked more closely.

This more accurate scheme is based on the relation

$$S = S_h F$$

where S = equivalent welding speed (spots per minute), S_h = welds per minute maximum (that is, the rate at which welds would be made with the same timer setting, if there were no rests for moving the gun or the work) = 3600/total cycles per weld; F = group duty factor read from Fig. 2. This chart is derived from "Rating of Electric Equipment under Intermittent Load," *A.I.E.E. Trans.*, **63**: 778 (1944).

As an example of the effect of grouped welds, consider the case of 150 assemblies per hour, each assembly having 12 welds made in 2 seconds. Welds per minute maximum (S_h) = 360. The average welds per minute are 30, which is the figure that would be used on Fig. 1 by the man who has not read this far.

But the actual equivalent welding rate to use in choosing cable from the chart is 58! This is obtained by placing a straight-edge on Fig. 2, between 150 assemblies (groups) per hour and an active time of 2 sec., noting where the straight-edge crosses the diagonal scale that the factor is 0.16, and multiplying 360 (S_h) by this value. That is, the equivalent welding rate is 360 × 0.16 = 58—a far cry from 30 "average."

So don't blame Fig. 1 if you figure a group-welding job by averages, and then find that the cable runs hot. The welding rate, as far as cable heating is concerned, may be a lot higher than you thought! Or, if cables are hot let's remember that other conditions must be met. It is not the fault of the chart if the water supply to the cable is just a thin stream.

The one other point that can be computed is "whether the cable will produce the required amount of welding current." This is not the right statement of the problem: since the cable is simply a path, it produces no current but merely allows it to flow. The current "producer" is the voltage supplied by the transformer. Therefore, getting adequate welding current may be considered a matter of attaching a transformer with high enough secondary voltage. So we must turn to transformer computations.

Choice of Transformer Size

Transformers are considered in this paper only because the correct size is one of the many essentials for getting satisfactory welds with any selected cable. The two points that bear on this relationship are the only ones considered here: the secondary voltage, and the kva. nameplate rating of the transformer.

Transformers are chosen all too often by comparison with the size transformer a pedestal-type welder would use for a similar job; or by remembering what kva. it took once before to weld the same gage of steel. This may frequently lead to the wrong size transformer because this process does not consider the fundamental factors affecting the situation. The following charts, although of an approximate nature, are basically sound because they

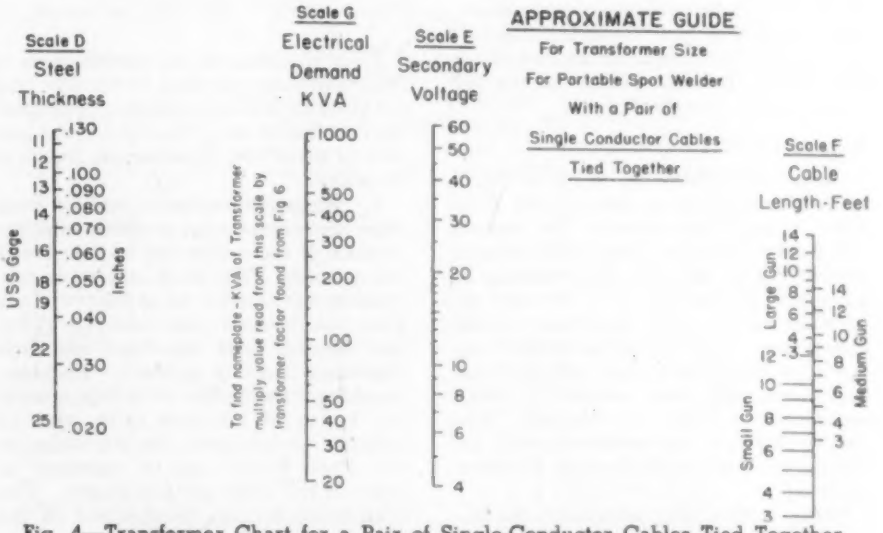

Fig. 4—Transformer Chart for a Pair of Single-Conductor Cables Tied Together, Giving the Same Data as Fig. 3 Shows for Low-Reactance Cable

Same conditions apply as for Fig. 3. Additional limitation: no magnetic material near cables. (If there is, Fig. 5, which requires higher voltages for same welds, will be more nearly correct for cables tied together.) This chart and Fig. 5 are based on 500 mcm cables, but any usual size will require essentially the same voltage and kva. in most cases.

"Small guns" means those with about 6-in. throats; "large guns" means those with about 30-in. throats.

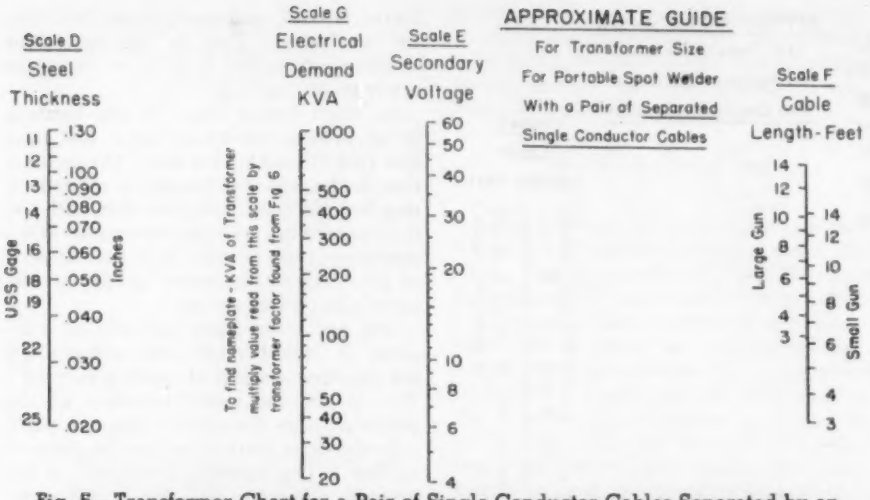

Fig. 5—Transformer Chart for a Pair of Single-Conductor Cables Separated by an Inch or More; Giving Same Data as Fig. 4 Shows for Cables That Are Tied Together

For average size guns, read voltage and kva. for small and for large guns, then use intermediate values.

do take into account the most important of these points.

One set of charts (Figs. 3, 4, 5) shows the voltage required to produce the secondary current necessary to make the welds; and also the kva. demanded from the transformer during each weld. The other chart (Fig. 6) relates the kva. demand to the nameplate rating of the transformer so that the heating effect may be taken into account. There are no serious problems in constructing Fig. 6, which is based upon the relation (see *Welding Handbook*, 1942, p. 288):

$$\text{Transformer factor} = \sqrt{2 \times \text{Duty Cycle}}$$

$$= \sqrt{\frac{2 \times \text{Welds per minute} \times \text{Current "On" Cycles per Weld}}{3600 \text{ (Cycles per Min.)}}}$$

Current "on" time is translated into metal thickness by the same standards as used for Fig. 1.

Developing Figs. 3–5, however, is rather involved and requires some explanation. The following section, "Basis for Charts," applies only to the problem of how to express simply the total voltage and kva. demand in order to make Figs. 3–5.

Basis of Charts

Since $E = IZ$ and $VA = EI = I^2Z$, it is necessary to know only I and Z in order to make these charts. The current I is known from the same AWS data as used in Fig. 1. The difficult problem is in impedance Z, because many elements go to make up the total impedance of the gun-welder. Charts could be made to include all the factors that influence this impedance, but they would be more formidable than their use warrants. The simple charts in this article account for the more important of the many variables involved.

Other factors may sometimes be important, but generally they are not. For present purposes they are called minor. To evaluate the minor variables, the electrical circuits for 68 complete welders covering a wide range of major and minor elements were computed. The following ranges of values were covered in these sample welders:

Steel welded	0.020–0.125 in.
Welding current	5000–20,000 amp. as determined by the steel
Duty cycle	0.1–0.25
Gun sizes	6–30-in. throat
Conducting material in gun	Copper, bronze
Cable types	Low reactance; single-conductor, tied; single-conductor, separated
Cable lengths	4–15 ft.
Transformer voltage	As required to furnish the current for each combination
Transformer kva.	As required to keep within rating at the duty cycle in each combination; also 75 kva. for all combinations requiring less
Transformer impedance	6%
Power supply	60 cycles per second

After studying the 68 combinations of these elements according to the way they are likely to be used in practice, the following conclusions were reached for the purpose of permitting approximate charts to be drawn:

1. When low-reactance cable is used, there are several ways in which total impedance of the welder can be linked with one variable. The most consistent relationship was found to be as follows: For a given size (circular mils) cable, the difference between total impedance and cable impedance is nearly constant. Therefore, by adding 0.6 milliohm to the impedance of any length of 275-Mcm cable, and 0.8 milliohm to 425-Mcm, the impedance of the whole welder can be expressed in terms of the cable size and length. This relationship permits development of the chart shown in Fig. 3.

2. For ordinary single-conductor cables, a chart can also be made, but greater liberties must be taken with limits of accuracy. It is found that an addition factor can be used as before, but because of the predominance of cable reactance over resistance, the impedance of the gun becomes more important in this case. The same high reactance means that cable size has less influence—which is fortunate because there are so many sizes from which to choose. This makes it permissible to omit cable size from the chart, and to make a practicable nomogram on the simple basis required for our purpose. This causes practically no error for separated cables, and decreases the accuracy only a few per cent when cables are bound together.

The following additions to cable impedance are used:

	Milliohms added to Cable Z in case of		
	Small Gun	Med. Gun	Large Gun
Cables tied together	0.55	0.80	1.20
Cables separated	0.70	0.85	1.10

These were obtained by a weighted average of the increments found in each example. A fortunate check is that they agree very closely with the quantities derived for the typical cases themselves.

Use of Charts for Transformer Size

To repeat, the purpose of Figs. 3–6 is to help select a transformer having: (*a*) high enough secondary *voltage* to send welding current through transformer, cable, gun and weldment; and (*b*) sufficient *size* (kva. rating) so the transformer will run cool.

To start with, the following decisions should already have been made: cable type, size and length; size gun; metal thickness; welding rate (corrected for intermittent welding as discussed under choice of cable size). Then the following procedure is used to select the transformer:

Step 1. Turn to Fig. 3, 4 or 5, according to type of cable being used.

Step 2. Using a straight-edge between known values on scales D and F, find the

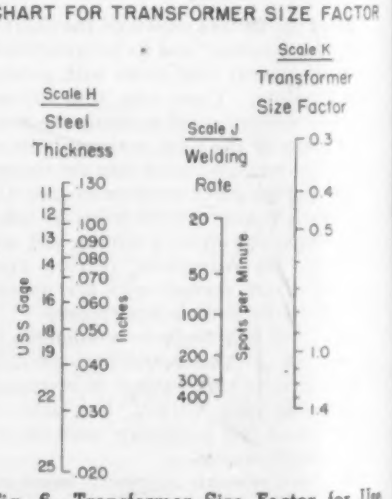

Fig. 6—Transformer Size Factor for Use with Figs. 3, 4 and 5—to Choose Sufficient Nameplate Kva. Rating So Transformer Will Not Over Heat

Chart is based on (*a*) A.W.S. welding technique; (*b*) adequate cooling of transformer; (*c*) transformer kva. nameplate rating at R.W.M.A. standard of 50% duty cycle; (*d*) assumption that transformer can handle nameplate kva. at all taps.

Table 3—Factors Favoring Large or Small Gun-Welder Cables

	Large	Small
Those that depend on experience		
Lightness of gun-cable assembly	..	X
Ease of handling	..	X
Long copper life	X	..
Electrical economy	X	..
Calculable		
Minimum investment:		
Cable	..	X
Transformer and controls	X	..
Total	X	..
Cool cable	X	..
Hot weld	X	..

secondary voltage where the line crosses scale E. Example: With a gun-welder having a 6-ft 275-Mcm low-reactance cable, weld 0.040-in. mild steel. A straight line on Fig. 3, between 0.040-in. on scale D and 6 ft. on the 275-Mcm side of scale F, crosses scale E at 10.0 volts. Pick a transformer with a somewhat higher nameplate voltage.

Step 3. With the straight-edge in the same place as above, read the kva. electrical demand from scale G. This tells how much power is drawn from the line during *each weld*, but transformer kva. depends also on *how often* it is drawn. To find the effect of "how often," take Step 4.

Step 4. On Fig. 6, from the known metal gage and average welding rate over a period of minutes, read the transformer size factor.

Step 5. Multiply the electrical demand by this factor. This gives the minimum kva. transformer size for the welding work. Example, Steps 3 to 5: Continuing the previous example, what kva. transformer is needed for 120 spots per minute? Figure 3 shows that for 0.040-in. steel, 6 ft. of 275 Mcm cable, the electrical demand (scale G) is 90 kva.

Figure 6 shows that the transformer size factor for 0.040-in. steel, 120 spots per minute, is 0.8. Multiplying 90 by 0.8 gives 72 kva. A 75-kva. transformer would be large enough for this setup.

New Standards Indicated

In contrast to ease of obtaining data upon which to base charts for cable size, the difficulty of correlating information for transformers was noticeable. There are two reasons. First, more variables and more uncertainties affect the required transformer voltage and kva. Second, lacking R.W.M.A. standards, the data on transformer and gun impedances that were available from published or private sources needed considerable reconciling.

Assuming that simplified charts of maximum accuracy are desirable, these difficulties point out the need for:

1. Standardization of *gun* welder transformer practice so that electrical characteristics can be stated with reasonable certainty.

2. Rating of transformers by their open-circuit secondary voltage and *secondary current capacity* (rather than kva.) at stated duty cycle.

The latter proposal has been made before and for other reasons. It is debatable, but there are sufficient good reasons for the change so that it should be seriously considered. The welding industry has decided to break with distribution transformer practice by rating transformers on a 50% duty cycle basis because that more nearly represents welding load. It could also logically choose to rate transformers not on kva. (which is used for distribution transformers because they are loaded with lamps, motors, etc., whose demand is best stated in terms of kva.), but on secondary current, which is a commonly accepted measure of the severity of the welding job, as shown by A.W.S. standards for welding technique. This would not only be simpler, but would give a more positive picture of the transformer characteristics which a kva. rating makes somewhat ambiguous.

From the viewpoint of charts, adoption of current-rating for welding transformers would reduce the process of selecting size. The required secondary current rating of a transformer for a welding operation would be simply the current required for each weld, multiplied by the transformer factor from Fig. 6.

General Use of Charts

The data presented here give approximate guides to selection of cable and transformer sizes for gun-welders. Selection of equipment from such charts on the basis of the work to be done will result in cable and transformer that will be right electrically. To the man who is used to picking the sizes by rule of thumb, the answers will sometimes seem out of line. For instance, although many men think it just natural that larger cables and larger transformers go together, they will find that for a given job the charts will call for larger transformers to accompany *smaller* cables. The basis for this is the same as that in which the *Welding Handbook* shows (p. 286) that smaller transformers cause greater demand on the electrical power supply.

The application of the methods outlined here will give welding men the feel of what governs size of portable welder cable and transformers, as well as provide numerical answers to jobs as they arise.

Appendix I

The chart of Fig. 1 is derived from the basic relation

$$I^2FRL = W \qquad (1)$$

where

I is the current through the cables
F is the duty factor
R is the effective resistance per foot of cable
L is the length of cable in feet
W is the watts carried away by the cooling water

For continuous welding:

$$F = \frac{\text{"On" time}}{\text{Total time}} = \frac{Sa}{3600} \qquad (2)$$

where

S = spots per minute
a = cycles "on" per spot

Substituting (2) into (1),

$$I^2aSRL/3600 = W \qquad (3)$$

R is a constant for cable of a specified cop-

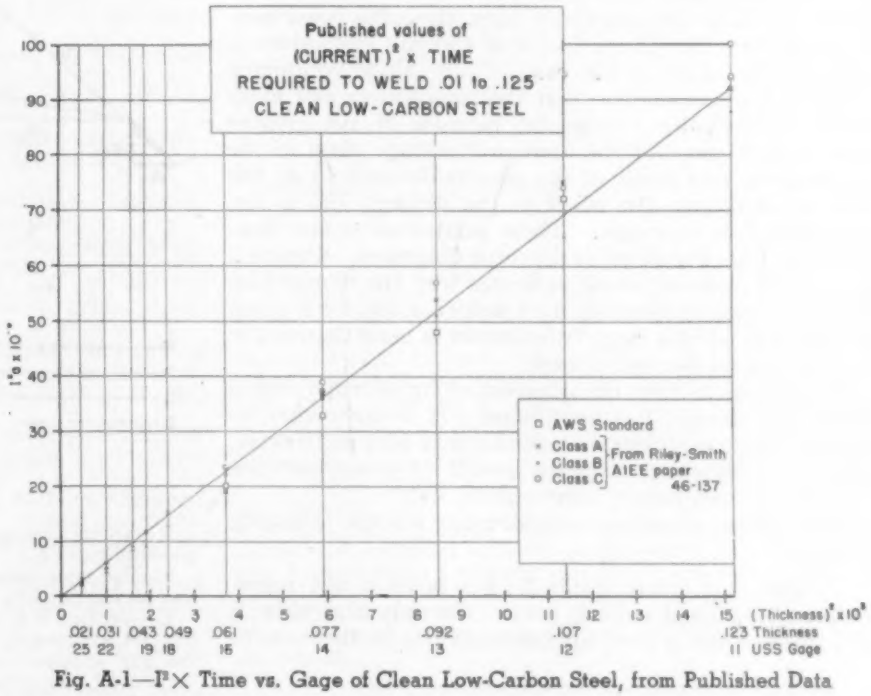

Fig. A-1—$I^2\times$ Time vs. Gage of Clean Low-Carbon Steel, from Published Data

per area operating at known temperature; W is a constant for a given temperature rise in the water (assuming the hot spot in the cable is at the same temperature as the outlet water), and given rate of water flow. Therefore

I^2aSL = constant for each cable size (4)

This relation is sufficient for a chart in terms of metal thickness, provided I^2a can be established for each thickness. Figure A-1 shows that with standard techniques for clean, low-carbon steel (to which this paper is limited, although the process can be used for other materials and conditions) there is not only a definite I^2a for each thickness, but a relationship covering all thicknesses from 0.01 through 0.125:

$$I^2a = kt^2 \quad (5)$$

where t = thickness of steel. Putting (5) into (4), we get

$$t^2SL = \text{constant} \quad (6)$$

This expression takes the nomographic form of Fig. 1.

Discussion

By A. C. Johnson*

MR. ZUCKER has undertaken a sizeable job in selecting this subject for a paper. It is a subject which is in need of work of this type since there is very little published data relating to it. The problem is complicated by the variety of requirements of portable gun welders. One need only consider the various sizes and types of work which are done with portable welding guns to appreciate the difficulty involved in attempting to write a paper which is generally applicable. Mr. Zucker is to be congratulated for a tough job well done!

In a paper of this type, it is often necessary to sacrifice accuracy for simplicity but, in spite of this, one of the main attributes of this paper is the fact that it is extremely useable. Some of the assumptions, for example, those which assume a constant impedance for the gun and transformer, are open to question; however, I have made a few spot checks of the chart presented in the paper against gun welders which just happened to be on the test floor at the time I read the paper and found the accuracy quite reasonable.

I take issue with Mr. Zucker's statement that in the case of single conductor cables, the impedance of the gun becomes more important because of the predominance of the cable reactance over the cable resistance. It is true that the power factor of the gun and cables is more nearly alike in the case of the single conductor setup and, consequently, that the impedances add more nearly numerically. However, because of the greater cable impedance and the increased voltage drop in the transformer as a result of the greater demand to do the same welding job, the effect of the welding gun is less pronounced in this case. These relationships are illustrated in Fig. 1 with typical vector diagrams. Figure 2 is a vector diagram which indicates why the demand on the power system imposed by a welder is less for a given welding job when a large transformer is used than is the case when a smaller one is used.

This brings to light the question of transformer rating which Mr. Zucker has mentioned. It is customary to rate welding transformers on the basis of 50% duty cycle, which I understand was the result of a compromise between the members of a committee.

This system of rating is inadequate for the following reasons:

1. The duty cycle selected as a basis is not representative of typical welding jobs. The only case where a 50% duty cycle is ever approximated is in the case of seam welders which represent a relatively small percentage of the output of welder manufacturers.

2. In any calculations pertaining to heating, it is always necessary to convert the rating to a continuous basis.

3. In many cases, the user of welding equipment is penalized on the basis of connected name plate load. This is ridiculous when it can be demonstrated easily that the demand is less for a given job for a larger transformer than it is for a smaller one.

4. Those in the industry have come to think of the requirements for a particular welding job in terms of so many kva. which, of course, has nothing to do with the ability of a transformer to deliver the necessary current.

I would suggest that the term "kva." be eliminated completely and that transformers be rated by specifying the maximum open circuit secondary voltage, the equivalent continuous secondary current that it will supply and the maximum secondary current which it will deliver in conjunction with the machine or gun with which it is associated.

This would also ultimately result in the elimination of the general practice of associating a welding job with so many kva. which is completely fallacious since the

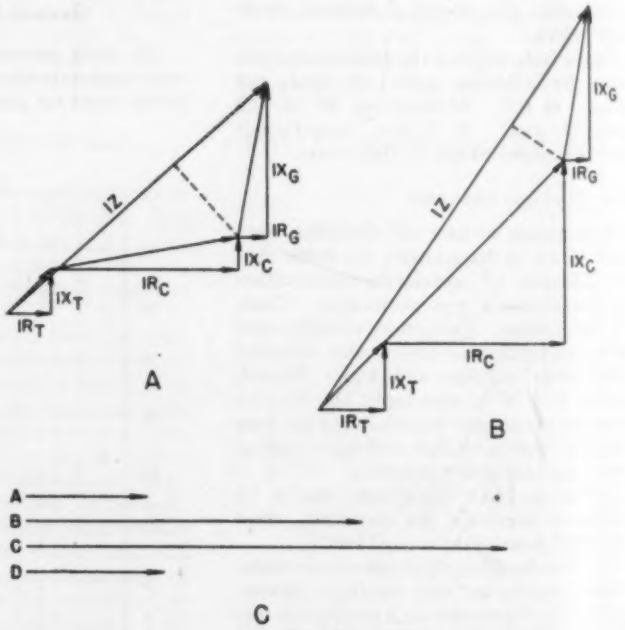

Fig. 1

A—Vector diagram of a typical welding gun transformer and the concentric cable.

B—The same gun and transformer with single conductor cable and set for the same welding current.

C—Vectors *B* & *C* are the open circuit voltages required in Fig. 1*A* & *B*, respectively. Vectors *A* & *D* are the components of the gun voltages in phase with the transformer voltage in Figs. 1*A* and 1*B*, respectively.

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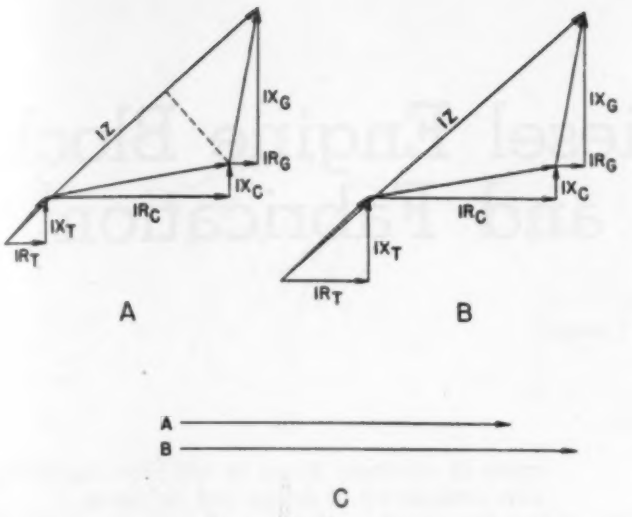

Fig. 2

A & B—Vector diagrams showing that the given welding job can be accomplished with the same gun and cable with less power demand using a large transformer than a smaller one. These diagrams are typical of the 100 and 50 kva. units.

C—Shows the open circuit voltages IZ in Figs. 2*A* and *B*.

kva. has nothing to do with the transformer's ability to accomplish a given welding operation but rather the rapidity with which that welding operation can be repeated.

There is one other detail on which I differ with Mr. Zucker and that is in the assumption that the outlet water temperature is equal to the hot spot temperature of the cable. The copper, especially in the center of the ropes which make up the cable, is often considerably in excess of the water temperature. Furthermore, there are usually local restrictions in water flow at the points at which the cable is suspended. There also exist hot spots at these points considerably in excess of the outlet water temperature.

There is no objection generally to operating the copper at temperatures of approximately 100° C., however, caution must be exercised in this respect because of the formation of steam pockets which reduce the cooling efficiency and will result in a further heat of the copper. This is dangerous from the standpoint of the cable life and also since it represents a personnel hazard because of the likelihood of excessive pressure bursting the water hose and scattering steam and boiling water. Generally speaking, it is advisable to limit the outlet water temperature to about 30° C. maximum temperature rise. This will result in a maximum outlet temperature of 40 to 60° thereby providing a sufficient allowance for hot spot temperatures.

In closing, I should again like to congratulate Mr. Zucker for his extremely worthwhile contribution to the art of welding.

(*Continued from page 222*)

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(*Continued on page 247*)

The Evolution of Diesel Engine Block Weldment Design and Fabrication*

By James W. Owens†

Introduction

AS IS generally known, the Diesel engine is one of the two major reciprocating types of internal combustion engines. The other type is the gas engine.

The principal operational differences between the types are the fuel used and the method of combustion. The Diesel engine uses a heavy fuel oil with a low flash point, which is ignited by the injection of the oil when compression of the air in the cylinder is at its maximum; whereas, the gas engine uses a gas or gasoline, which is ignited by an electric spark at maximum compression.

Both types of engine require "blocks" of definite functional forms (shapes)[1] to take care of a potentially wide range of operational features; which should be very carefully engineered to provide uniform, consistent and ample strength; also ample rigidity to resist the forces involved. In addition, "wet" blocks must be tight.

To date, Diesel engine blocks have been iron castings, aluminum castings and steel weldments. However, whether a block is made by these processes, by any other processes or with any of these materials, should, or will be, determined by the following technical, production, managerial and/or sales variables:

1. Permissible weight of engine as determined by the type of service—stationary or mobile (railroad, automotive, marine and air).
2. Horsepower required per engine—10 to 5000 or more.
3. Production requirements—1 to 1000 or more per month.
4. Available manufacturing facilities—foundries weldries and/or types of machine shop tools.
5. The attitude of top management toward, and the relative backing given the utilization and development of the various processes.
6. The relative current and anticipated turnover of foundry and weldry labor due to working conditions and the increased cost of manufacture from this cause.
7. Type and/or competency of the technical force; supervision and supervisors; labor; inspection and inspectors.
8. Whether full freedom of design is possible or permitted for the blocks to be compared, or whether the designer is restricted to the limitations imposed by the existing design.
9. Fabricating problems as affected by process (hard spots in castings, fit-up in welding), material, size, complexity of design and tightness.
10. Scrap losses and/or the over-all salvage cost of all operations involved, including testing, machining and inspection.
11. Cost of the machined block delivered to the assembly floor.[2]
12. Assembly costs of the block as affected by a small vs. a large number of parts.
13. Shipping costs as affected by weight of block.
14. Delivery dates as affected by lost time due to scrap as contrasted with the possibility of adhering to delivery dates by being able to salvage the block and other parts of the engine during manufacture.
15. The importance placed by the manufacturer and user on the predictable reliability of the block in service, both as regards strength and tightness, and the possibility of salvaging physical damage.
16. Last but not least, the importance placed by the manufacturer on good will as affected by items 14 and 15.

In view of the foregoing variables, it is impossible for any individual to arbitrarily specify the process or material by or with which some specific block should be fabricated. Each manufacturer and user of Diesel engines must, on the basis of all of these variables, settle this problem to his own satisfaction. This conclusion is applicable also to the fabrication of numerous other products including Diesel engine locomotive underframes and trucks. What the author does know is:

That he has seen block weldments produced at one-fifth of their original cost by a re-design which appreciably reduced the amount of fit-up, welding and machining; by the use of an incentive method of payment; and by appropriate tooling, even though the individual earnings of all workers had appreciably increased.

That he has seen machinery weldments designed and fabricated under his direction which should have cost less than competing castings, but which actually cost more because one or more of the variables listed adversely affected their cost. *This specific conclusion is also applicable to the high cost of some of the weldments occasionally featured in the technical press by those sponsoring or advocating competing processes.*

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* Presented at Twenty-Seventh Annual Meeting, A.W.S., Atlantic City, N. J., week of Nov. 17, 1946.

† Director of Welding, Fairbanks, Morse & Co., Beloit, Wis.

[1] See Fig. 1. These illustrations are from a paper on "Diesel Engine Design Trends," by Edward C. Magdeburger in the June 1944 issue of the *S.A.E. Journal*, and is published with the permission of the Society.

[2] "Cost per pound" is very misleading and should never be used by management, engineers or purchasing agents as a basis for comparing the cost of weldments with iron, steel and/or aluminum castings. Assuming that the total cost of a weldment was less than that of a comparable iron casting, its cost per pound would undoubtedly be more as weldments are invariably lighter than iron castings. The converse is likely to be the case for aluminum castings. The unreliability of this method is further accentuated in large Diesel engine blocks wherein the number of cast parts have to be increased so as to use this process, thereby increasing the cost of subsequent machining and assembly operations to the advantage of possible one-piece weldments, or weldments having fewer pieces than the competing castings.

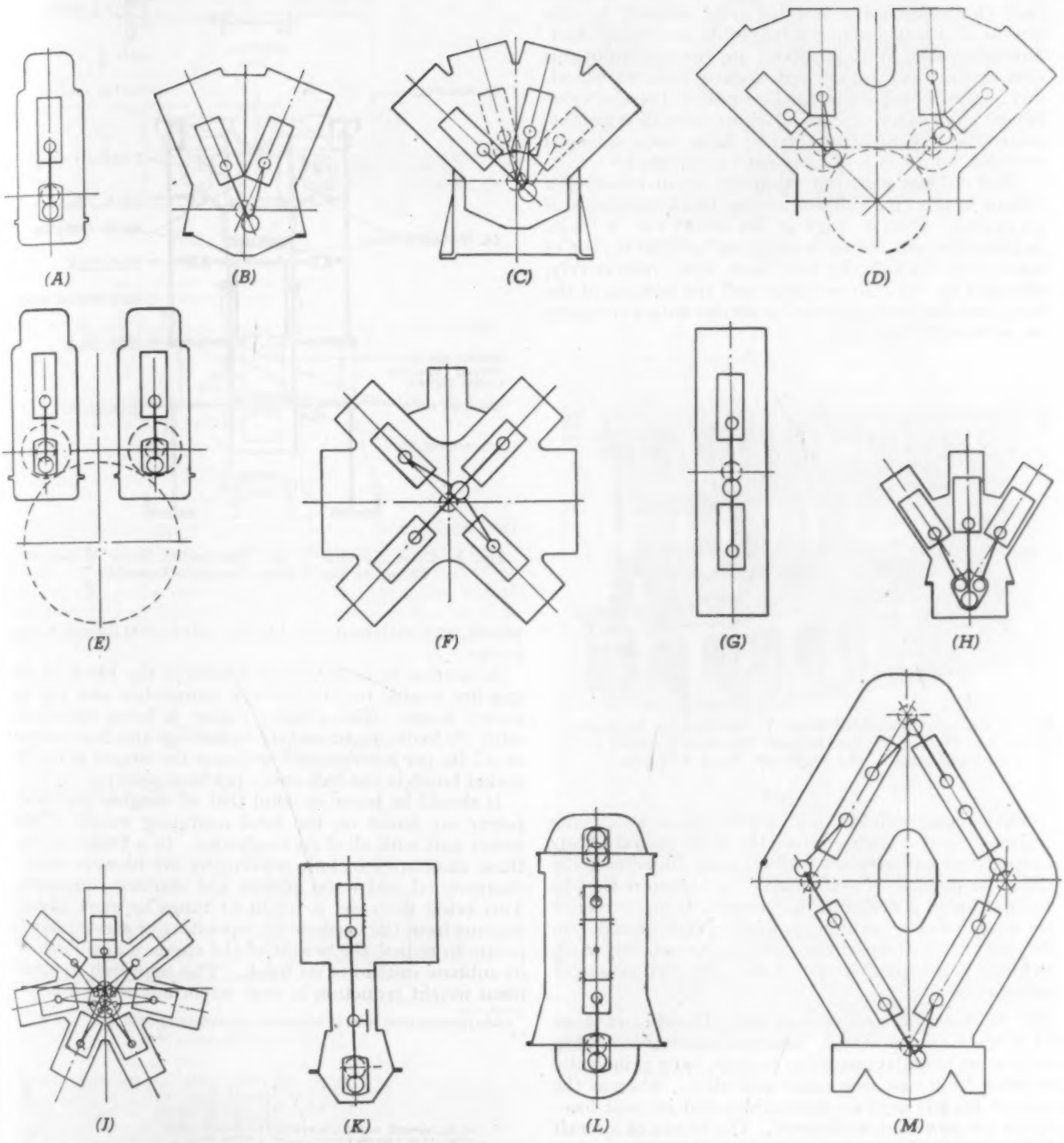


Fig. 1—Typical Cross Sections of Diesel Engines, Showing the Wide Variety of Forms (Shapes) of Blocks Produced by Various Combinations of Cylinders, Pistons and Crankshafts (All Blocks Drawn to the Same Scale)

(*A*) Basic 2-cycle, one-crankshaft type, with uniflow scavenging. (*B*) Standard V, one-crankshaft type (manufactured in 6-, 8-, 12- and 16-cylinder sizes). (*C*) Porcupine, one-crankshaft type (4-cylinders arranged as two V's). (*D*) Double-V, two-crankshaft type. (*E*) Quad, one-crankshaft type (4-engine unit of 24 cylinders). (*F*) Pancake, one-crankshaft type (4 cylinders in the same plane). (*G*) Vertical, one-crankshaft opposed cylinder type. (*H*) Three-bank, one-crankshaft type (W arrangement of cylinders). (*J*) Radial, one-crankshaft type (normal type of aircraft radial engine). (*K*) Double-acting one-crankshaft type. (*L*) Standard opposed piston (O.P.) type, two crankshafts (manufactured in 3-, 5-, 6-, 7-, 8-, 9- and 10-cylinder sizes). (*M*) Diamond opposed piston (O.P.) type (4 cylinders in the same plane and 4 crankshafts).

That of the thousands of block weldments fabricated for engines of the type, bore and stroke, shown in Fig. 8, there has been only one rejection. Furthermore, that this rejection is not regarded as such by the author as it was due to a salvageable machining error. Salvaging was, quite properly, not resorted to in this case as the block would vary slightly from the standard. It was assigned to the Company's Diesel Engine School. All other machining errors, also all rejectable materials and welding defects, have been salvaged *regardless of the state of completion of the block.*[3]

That he has seen the relatively small effect of a serious locomotive collision on the block weldment of its engine. Such damage as did occur, viz., a $^1/_8$-in. deformation of a thrust bearing and a 0.020-in. out of roundness of a cylinder liner bore, were, respectively, salvaged by precision welding[3] and the bushing of the bore, and the block returned to service with a complete set of standard parts.

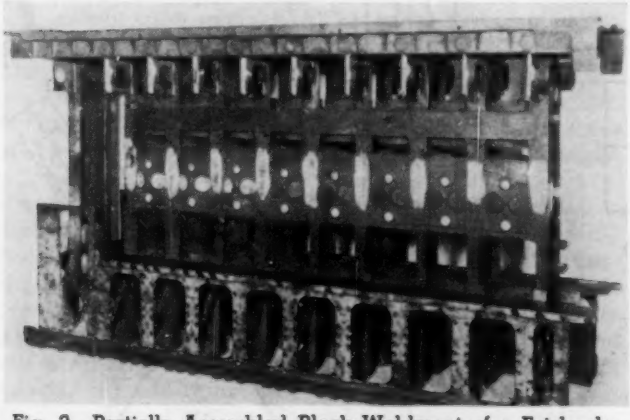


Fig. 2—Partially Assembled Block Weldment of a Fairbanks, Morse & Co's. 8 x 10 Superseded "Standard Type of O.P. Diesel Engine." An 8-Cylinder Block Is Shown

That he has seen locomotive underframe weldments manufactured at costs appreciably lower than the costs of cast steel underframes with all parts added to make them comparable to weldments. Furthermore that he has not found it desirable or necessary to stress relieve these underframe weldments and expects to make, in the not distant future, the same statements for truck weldments for his Company's switcher and passenger locomotives.

The blocks of all sizes of stationary Diesels and those used in truck transportation, in some locomotives and in most marine installations have, to date, been principally fabricated from cast iron (gray and alloy), whereas the blocks of Diesels used on submarines and in most locomotives are now steel weldments. The blocks of aircraft Diesels, with the lowest horsepower-weight ratio requirements, have been cast aluminum.

The German Junkers' opposed piston Diesel engine is a classic example for low-weight engines with aluminum blocks, as it weighs only 1.3 lb. per horsepower.[4] However, the author desires to state that he has no information on the costs and service life of this block as influenced by the use of this material. Furthermore, it should be borne in mind that aircraft engines have essentially short service lives.

Diesel engines which have been equipped with steel block weldments have usually been 10 to 75 lb. per horsepower, and with cast-iron blocks—20 to 200 lb. per horsepower.

[3] See paper by the writer on "Routine Inspection and Salvage of Machinery Weldments," THE WELDING JOURNAL, October 1944.

[4] See the use of this term in the writer's book, *Fundamentals of Welding*, Penton Publishing Co., Cleveland, Ohio, pp. 230–233, also in the First and Second Editions of the *Welding Handbook*, Chapters 3 and 4A, respectively.

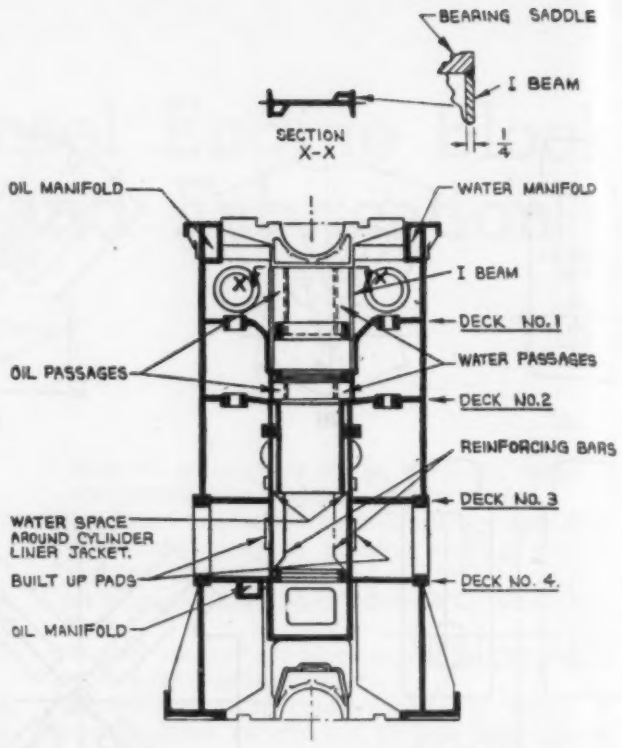


Fig. 3—Cross Section of the Superseded Block Weldment Shown in Fig. 2 After Complete Assembly

Indicative of evolutionary trends is the block of the gasoline engine for the Crosley automobile and the V2 rocket bomb. The Crosley engine is being fabricated with 120 hydrogen brazed steel pressings and has a weight of 5.7 lb. per horsepower,[5] whereas the weight of the V2 rocket bomb is one-half ounce per horsepower.

It should be borne in mind that all weights per horsepower are based on the total operating weight of the power unit with all of its auxiliaries. In a Diesel engine, these auxiliaries include scavenging air blowers, superchargers, oil and water pumps and starting equipment. This being the case, it might at times be more advantageous from the engineering, operating or service standpoints to reduce the weight of the engine's auxiliaries or its subbase instead of its block. This approach to maximum weight reduction is very important when it is de-

[5] See January 1946 issue of *Materials and Methods*, p. 438.

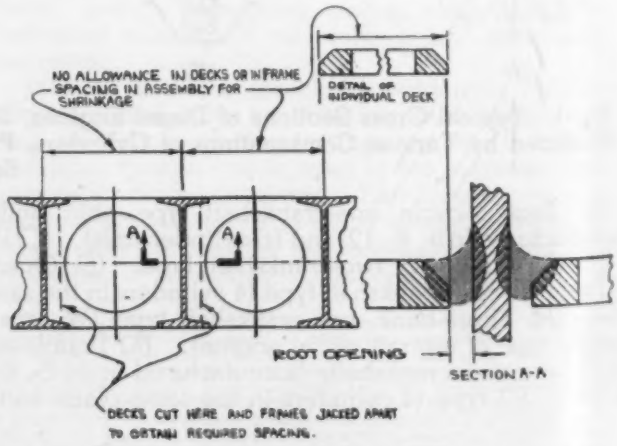
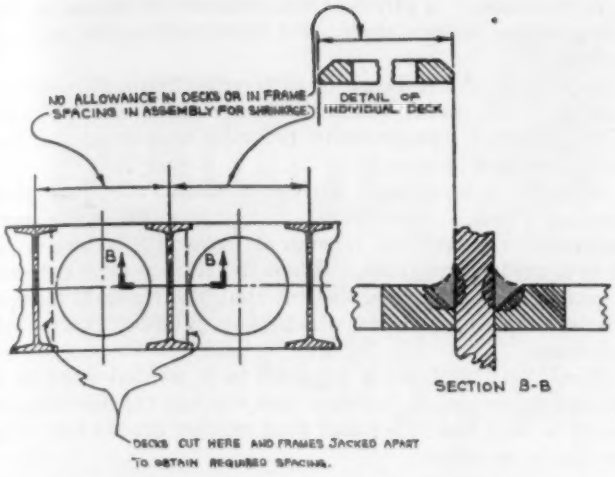

NO ALLOWANCE IN DECKS OR IN FRAME SPACING IN ASSEMBLY FOR SHRINKAGE
DETAIL OF INDIVIDUAL DECK
A
A
ROOT OPENING
SECTION A-A
DECKS CUT HERE AND FRAMES JACKED APART TO OBTAIN REQUIRED SPACING.

Fig. 4—First Design of Center Decks Used in the Superseded Block Weldment Shown in Fig. 2.


NO ALLOWANCE IN DECKS OR IN FRAME SPACING IN ASSEMBLY FOR SHRINKAGE
DETAIL OF INDIVIDUAL DECK
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B
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DECKS CUT HERE AND FRAMES JACKED APART TO OBTAIN REQUIRED SPACING.

Fig. 5—Second Design of Center Decks Used in Superseded Block Weldment Shown in Fig. 2

sired to utilize the inherent advantages of steel as a material for block construction.

Definitions

The author's approach to the design, fabrication and inspection of machinery weldments, ships' hulls and weldments in general, and his conclusions, have been revolutionized due to the perfection of practical and economical visual aids for the detection and differentiation of surface and subsurface discontinuities. Consequently, he has found it necessary to make a number of revisions and additions to the Society's standard nomenclature for clarity and other reasons. These revisions and additions are as follows:

Residual Stress.—The summation of reaction and triaxial stresses remaining in a joint or in a structure as a result of thermal or mechanical treatments or both.

Reaction Stress.—That proportion of residual stress which could not exist in a joint or in a structure if the component members of the joint or of the structure were free to move and/or deform during welding. This restraint not only modifies, *but can modify dangerously, the residual stress (and therefore also the crack and tear) patterns* in a joint, in previously welded joints, and in the structure as a whole.

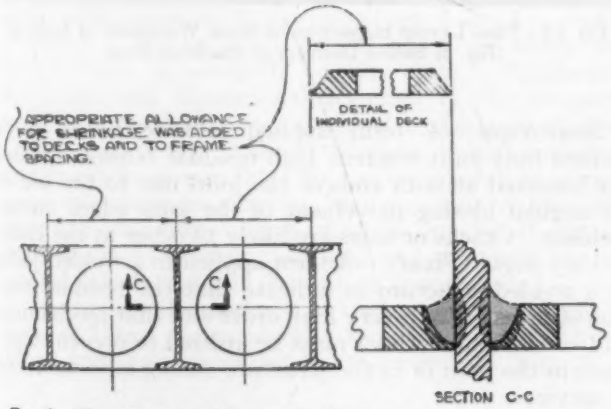

Fig. 6—Third Design of Center Decks Used in Superseded Block Weldment Shown in Fig. 2

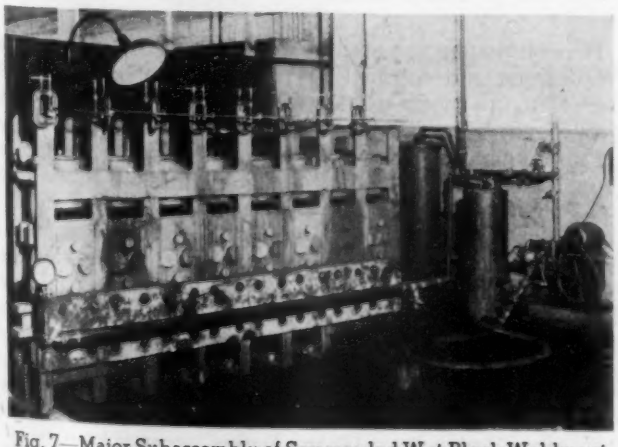

Fig. 7—Major Subassembly of Superseded Wet Block Weldment Shown in Fig. 2. Weldment Being Hydrostatically Tested

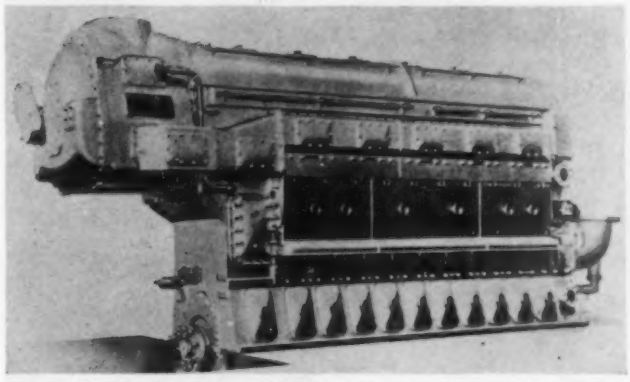

Fig. 8—Fairbanks, Morse & Co's. 8 1/8 x 10 "Standard Type of O.P. Diesel Engine." 10-Cylinder Engine Ready for Shipment

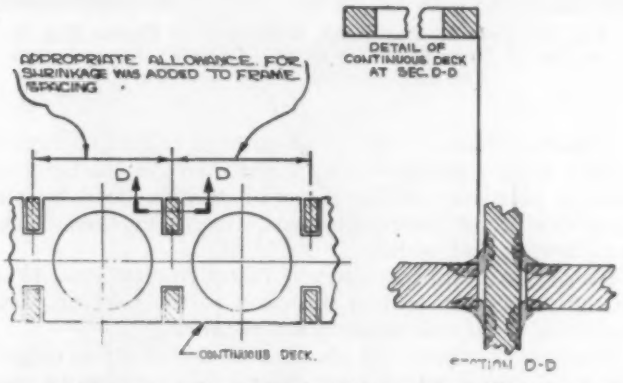

Fig. 9—Design of Center Decks Used in Block Weldment of Engine (Fig. 8)

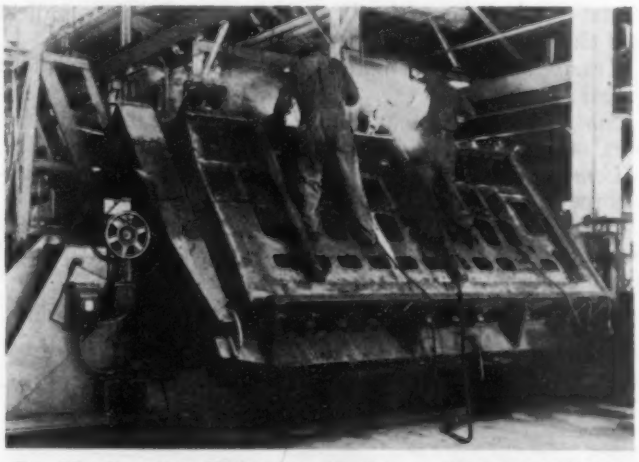

Fig. 10—Assembly Welding in Positioner of Block Weldment of Engine Shown in Fig. 8

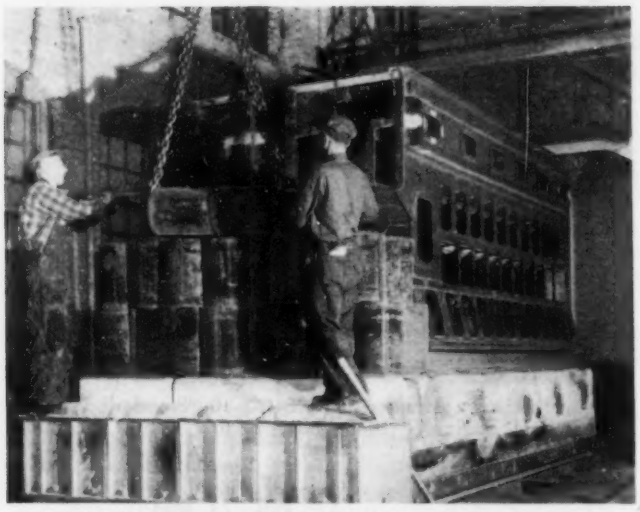

Fig. 11—Loading Two Block Weldments of Engine (Fig. 8) on Car of Stress-Relieving Oven. Cylinder Liner Jackets Also Being Loaded on the Same Car

Triaxial Stress.—That proportion of residual stress in a joint or in a structure which is due to the plasticity or lack of plasticity of the material as influenced by the geometry of the component parts, including their thickness, length and width.

Notch.—An abrupt surface discontinuity due to a change in section and/or direction of the part or parts involved. It is essentially a stress raiser.

Fracture (Failure).—A physical discontinuity in originally solid metal, which may extend into contiguous material, parts and/or structural members.

Crack.—A fracture which may or may not be visually observed, but is more readily detected and observed by visual aids. Geometrically, it is potentially the smallest and the most dangerous type of "notch."

Tear.—A fracture which is very readily observed without visual aids.

Simple Tear.—A tear which is restricted to the metal, part or member involved.

Compound Tear.—A tear which extends into contiguous metal and/or structural members.

Simple-Compound Tear.—A tear which extends into contiguous metal, but is restricted to the part or structural member involved.

Fig. 12—Final Magnaflux Inspection of Block Weldment of Engine Shown in Fig. 8

Lamination.—A physical discontinuity in metal, originating in the molten state, and restricted to the part involved.

Segregation.[5]—A layer of different chemical composition than the metal on each side of it and wherein there is no physical discontinuity between this layer and the metal on each side of it.

Rigid.[6]—A term used with or without the qualifying prefixes "non," "semi" and "very" to express the summation of the residual tension stresses in a welded joint or in a welded structure. When the term is used without a qualifying prefix, it indicates that the residual tension stresses are of an order which may produce cracks but not tears.

Non-Rigid.[6]—A term applied to a welded joint or a welded structure, to indicate that residual tension stresses are of a very low order and that neither cracks nor tears are likely to occur.

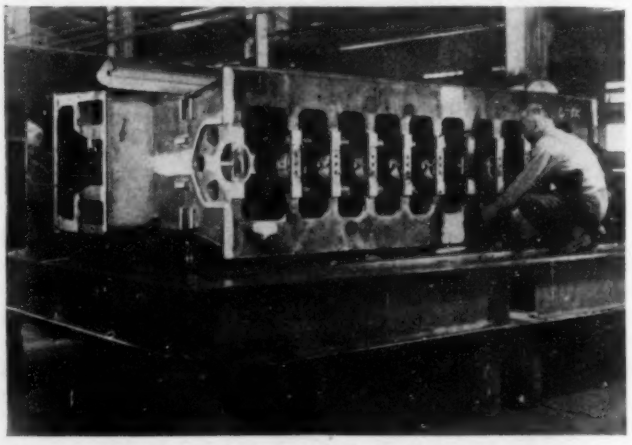

Fig. 13—Final Layout Inspection of Block Weldment of Engine (Fig. 8) Before Delivery to Machine Shop

Semi-Rigid.—A term applied and restricted to a welded butt joint wherein high residual tension stresses are localized at both ends of the joint due to the use of an angular closing movement of the joint edges during welding. Cracks or tears are likely to occur at the ends.

Very Rigid (Fixed).—A term applied to a welded joint or a welded structure to indicate that the residual tension stresses are of a very high order and that mechanical and/or thermal methods must be utilized to prevent fractures in the joint or in the structure during fabrication or in service.

The Evolutionary Approach

It is obviously impossible to describe the evolution of the designs and fabricating procedures of all forms of Diesel engine block weldments. Therefore, only blocks of one general type—Fig. 1 (*L*), and of approximately the same bore and stroke of which the writer has intimate knowledge, or which were designed and/or fabricated under his direction, will be discussed.

In our company's first efforts to fabricate block weldments, no major assembly fixtures were used; designs were unsuitable; and either no allowance or unsuitable allowances were made for shrinkage. As a result, it was found that the obtaining of the required close three-dimensional tolerances was a major fabricating problem. Furthermore, the securing of consistently tight joints

[6] See paper, "Junkers Heavy Oil Aero Engines," presented before the Lilienthal Gesellschaft für Luftfahrt, Berlin, October 13, 1935, and published in *The Engineers*, February 5, 1937, issue.

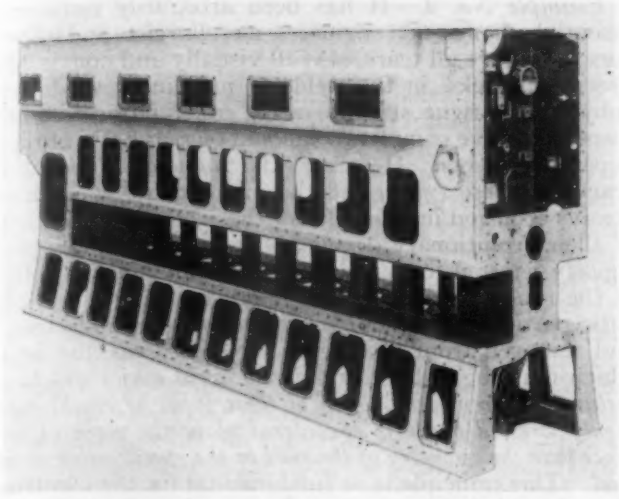

Fig. 14—Machined Dry Block Weldment of Engine (Fig. 8) Ready for Delivery to Assembly Floor

appeared at times to be an insurmountable problem due to the large amount of welding required by the design; the type of joints used; the inaccessibility of the welds; magnetic arc blow or the extreme fixity of the structure with resulting cracked welds. As a consequence, some of these first blocks were, during fabrication, cut apart in various locations and re-welded. Furthermore, after completion, it was found necessary to scrap a number of them for various reasons, including poor workmanship.

In the evolution of these block weldments, problems of tightness were progressively solved by a reduction in the number of joints which had to be tight; by the use of J-butt welds with complete root penetration (Fig. 6) instead of single bevel butt welds (Figs. 4 and 5); and by the use of mechanically assembled parts which were tested prior to assembly in the block. Problems of shrinkage and dimensional accuracy of the completed weldment were solved by appropriate dimensional allowances for shrinkage in the detail parts, in sub-assemblies, and in the final assembly; by the use of shrinkage specimens to determine these allowances; and by the use of carefully designed and accurately machined fixtures, together with carefully planned and progressively controlled fabrication and inspection procedures.

The technical soundness of the company's current designs of Diesel engine block weldments as typified by the block and some of its details shown in Figs. 8 to 18, inclusive, has been verified by physical tests of main frame sections and of completely machined block weldments prior and subsequent to their routine production. A shrinkage and tension test specimen is shown in Fig. 16, also torsion and bend tests of completely machined block weldments in Figs. 17 and 18.

In these designs, there have been no problems of dimensional tolerances which have not been solved; there have been

Fig. 15—Block Weldments of Engine (Fig. 8) on Assembly Floor

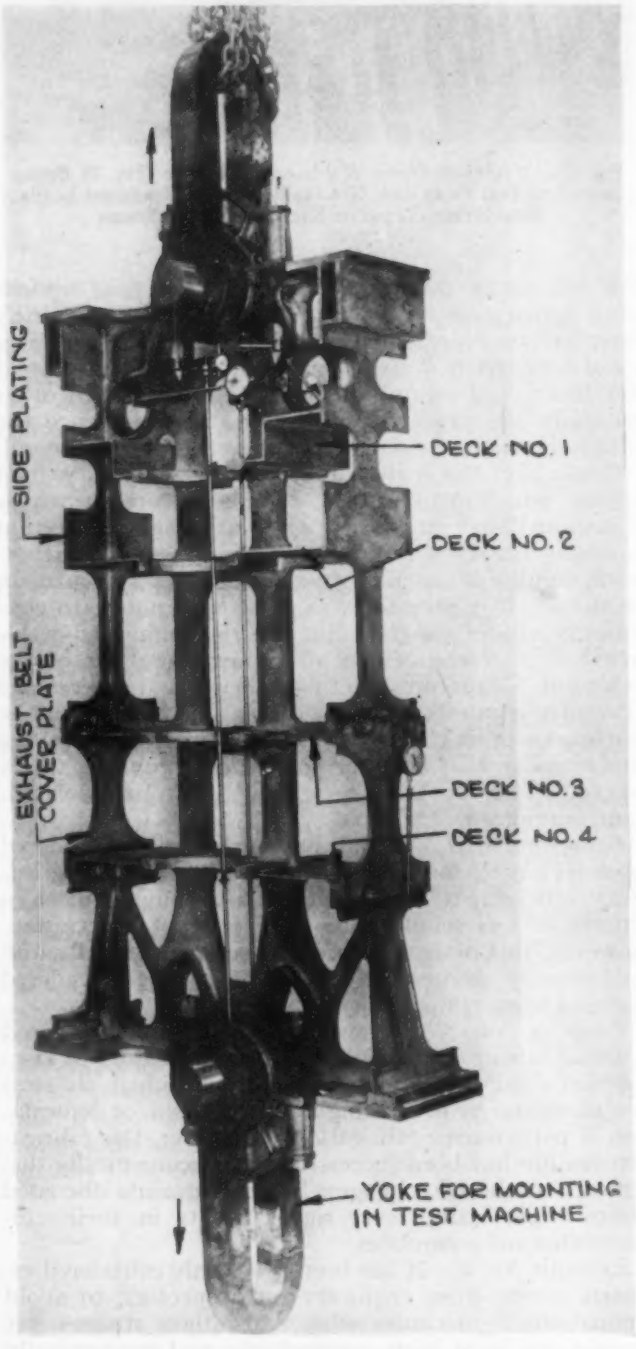

Fig. 16—Tension Test Specimen of a Main Transverse Frame with Unit Sections of Decks, Side Plating and Exhaust Belt Cover Plates as Used in Block Weldment of Engine Shown in Fig. 10. Specimen Was First Used as a Shrinkage Specimen

no failures on the test floor or in service of a block weldment of the thousands of engines which have been sold subsequent to 1938 for marine, stationary and railroad service. Furthermore, as previously noted, blocks damaged in service are being salvaged and returned with standard parts; and there has been only one rejected block during fabrication, and this was

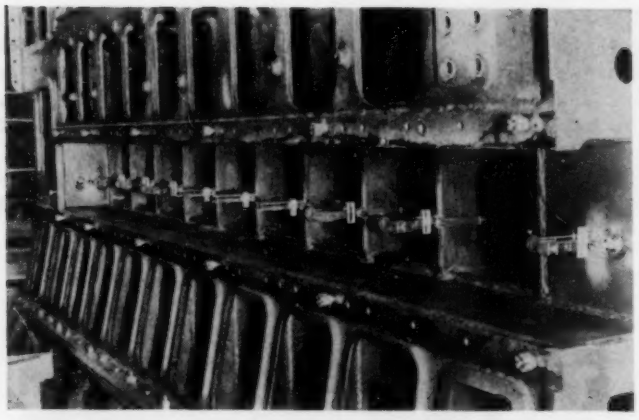

Fig. 17—Machined Block Weldment of Engine (Fig. 8) Being Tested on Test Floor with Gradually Applied Torsional Loads. Note Strain Gages on Each Transverse Frame

also salvageable. Again, fabrication cracks and laminations[7] *which were at first a problem have been completely solved with the aid of magnetic particle inspection and by the use of appropriate steels.* For products of this type and size, this record not only challenges competition by other materials and processes, but should also challenge the imagination of industrialists and manufacturers in general.

Personally, the writer does not know of any welded product which involves so many fundamental principles of welding design and so many fabrication and inspection problems as a Diesel engine block weldment.[8] Furthermore, because of machining requirements and mechanism clearances, it is necessary, as previously noted, to consistently obtain triaxially (in the rough finished weldment) close tolerances on all component parts of the weldment. To accomplish this, he has found it necessary to resolve a number of principles and problems in the drafting room, in the shop and with inspection by taking into consideration other principles and problems which are sometimes contradictory when they are isolated. Four examples will be cited:

Example No. 1.—It has been arbitrarily considered essential among some engineers regardless of impracticability and cost, that all joints of a machine subject to fatigue stresses should have complete root penetration. However, this design feature has been successfully and economically disregarded whenever it was considered essential to economic design.

Example No. 2.—It has been arbitrarily considered essential among some engineers and fabricators to keep reaction (and therefore the ultimate residual stresses) at a minimum by permitting movement and/or deformation of parts during fabrication. However, this fabrication feature has been successfully and economically disregarded as the Diesel engine block weldments discussed utilize "rigid"[7] and "very rigid"[7] joints in their subassemblies and assemblies.

Example No. 3.—It has been arbitrarily considered essential among some engineers and inspectors, to avoid laminations in machines subject to fatigue stresses, yet laminations have been satisfactorily and economically permitted, under certain conditions, to remain in the completed weldment: (*a*) if not found in the parts by magnetic particle inspection and eliminated prior to their assembly in the structure; and (*b*) if "non-objectionable"[9] on the basis of pre-established inspection standards.

Example No. 4.—It has been arbitrarily considered essential among some engineers, metallurgists and inspectors to remove all tears, also all visually and nonvisually observed cracks[7] in the welds of machinery weldments subject to fatigue stresses, while other fabricators and inspectors have completely ignored one, or both, of these types of defects. However, the *numerous* fabrication cracks of these types, and the minor tears, which have always occurred in the welds of these blocks in all stages of their evolutionary development, because of the joint rigidity referred to in Example No. 2, are, on completion of the rough weldment, sought out and found by magnetic particle inspection, *before and after stress relieving*,[10] and removed from the highly stressed areas and areas which must be tight. *In order to avoid major structural failures, the removal of both of these types of cracks from highly stressed areas is considered of vastly more importance than the geometry of the part or the specification of the steel.* This principle is as fundamental for the construction of welded ships' hulls as in Diesel engine construction.

Tightness and Its Effect on Design

The author, in his design and fabrication of Diesel engine block weldments, has had an excellent opportunity to observe the problems of tightness and its effect on the design, fabrication cost, service problems and service life. As water leaks can be a serious operating problem if water gets into the oil, it is absolutely essential, in the design of cylinder blocks, to use every possible precaution to localize leaks and facilitate their stoppage during fabrication and in service.

If, as pointed out in Example No. 4, it has so far been found impossible, to prevent cracks during fabrication and stress relieving, it does not require much imagination to picture the problem of tightness as affected by such cracks and by laminations in the steel. Therefore, those sections of the block and its mechanical assemblies wherein tightness is required should be hydrostatically tested both before and after stress relieving, and at pressures which may be as high as 100 psi., in some designs.

Another problem which has to be faced in the manufacture of cylinder blocks and mechanical assemblies which have to be tested for tightness is the effective closing of unmachined and warped openings. Hydrostatic testing, while costly, is essential to inspection.

[7] See paragraph on Definitions.

[8] The general structural form of the block weldments described herein is very similar to a ship's hull with its transverse bulkheads, decks and shell plating. The welding fabrication stresses are also similar.

[9] For classification and analysis of "objectionable" and "nonobjectionable" laminations, see paper by the author on "Routine Inspection and Salvage of Machinery Weldments" in October 1944 issue of THE WELDING JOURNAL.

[10] Some cracks are invariably found after stress relieving even though a thorough magnetic particle inspection before stress relieving had indicated that the block was free from cracks. *For such cracks, there are two possible explanations:—(a) A variation in the heating and cooling rates of adjacent light and heavy sections, even though the thermal cycle is thermostatically controlled and the blocks are not removed from the furnace until the temperature has been lowered to 250° F. and—(b) Stress relieving increases the magnetic sensitivity of the steel, with the results that cracks which were not found before stress relieving are readily detected after stress relieving.*

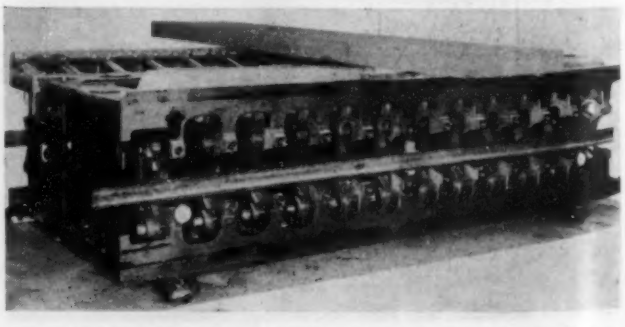

Fig. 18—Machined Block Weldment of Engine (Fig. 8) Being Subjected to a Bend Test with Gradually Applied Loads

Main Transverse Frames and Block Strength

When the transverse frames of a Diesel engine block are its major strength members, each frame is required to repetitively withstand the reaction force of the explosions in the cylinders and the force of inertia of the moving parts. The summation of these forces on a frame will vary from zero to maximum during each cycle, variation depending on the firing order and the form of block. The value of the explosion forces for the various types and sizes of Diesels varies from 600 to 2000 psi.

It should be observed that the main transverse frames of the engine blocks discussed are required to withstand the explosion and inertia forces throughout their entire length—i.e., from the bearing block welded on one end to the bearing block on the other end. This is an ideal design and service condition, as the only mechanical connections required to withstand the forces involved, and which require no special service adjustments, are the four short studs or bolts connecting the bearing caps to the bearing blocks, also the studs and dowels attaching the cover plates of the exhaust belt to the block.

The Evolution of Fabricating Facilities

The writer has called attention to the fact that among the factors determining the construction cost of block weldments are the fabricating facilities of the shop or shops in which the weldments are built. Therefore, before outlining the evolution of fabrication and inspection procedures, it would appear desirable to give the reader some idea of the type of equipment to be expected in properly equipped weldries, viz., weldries which can profitably compete with well-established foundries.

The company's Diesel engine block weldments in their experimental and developmental stages were fabricated in a shop which had only one straight-line flame-cutting machine, two 300-amp. d.-c. arc welding MG sets and a few elementary assembly and welding fixtures, including one cast-iron assembly slab provided with slots for assembly bolts. In comparison, the company now has two fully equipped weldries which are complementary and supplementary to each other. In one or both of these weldries one finds plate storage and shipping bays; tool cribs for the filing, storage and issuance of drawings, tools, templates and fixtures; and the following departments set up as independent processing units: template and die making, flame cutting, slagging, forming, welding cleaning and salvage.

The flame cutting departments have two-torch straight-line and four-torch contour flame cutting machines; the slagging departments are equipped with cast-iron slagging tables and pneumatic slagging hammers; and the forming departments are provided with shears, nibblers, rolls, do-all saws, and hydraulic presses with a maximum capacity of 1500 tons. The welding departments are equipped with an ample number of suitably arranged cast-iron shipyard assembly slabs; 300- and 500-amp. a.-c. transformers for manual welding; a 1500-amp. transformer for an automatic welding gantry; positioners of various sizes; straightening presses; welding slabs; inspection and layout tables. The cleaning departments are provided with cast-iron cleaning slabs and pneumatic hammers, shot blasting rooms, stress relieving and annealing ovens, equipment for oil and water testing and paint spray booths.

The Evolution of Fabrication and Inspection Procedures

The major evolutions in fabrication and inspection procedures in our company's weldries are:

1. The use of shrinkage specimens, prior to routine production, for weldments involving close tolerances.
2. The use of carefully machined and installed shipyard assembly slabs, also carefully machined fixtures with the necessary shrinkage allowances for the assembly of repetitive weldments involving close tolerances.
3. The use of quality flame cutting[3] so as to obtain surface finishes which do not require the use of supplementary finishing operations.
4. The use of grinding only when specified on drawings or otherwise authorized.
5. The use of temporary tie bars, tie plates or struts to obtain dimensional accuracy of detail parts when flame cut and of subassemblies when welded.
6. The production use of a.-c.—d.-c. magnetic particle inspection to detect surface and subsurface discontinuities and to differentiate between those which are relevant and nonrelevant.
7. The shotblasting of all weld faces to be subject to magnetic particle inspection.
8. The progressive inspection of each detail and each subassembly, also of the final block assembly, so as to avoid accumulation of defects which would increase the cost of fabrication or cause rejection of the completed weldment. This inspection of the final block assembly and its welding has been combined on one production and inspection form. Provision has been made on this form for the signatures of department foremen and company inspectors responsible for the operations involved. On blocks wherein customer inspection is involved, provision is also made for the signature of these inspectors, but not until the operation has first been inspected by the company's inspectors.

(*Continued from page 239*)

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THE AMERICAN WELDING SOCIETY

ACTIVITIES — RELATED EVENTS

MINUTES OF THE MEETING OF EXECUTIVE COMMITTEE, AMERICAN WELDING SOCIETY

The meeting was held on Dec. 14, 1946, A.W.S. Headquarters, Engineering Societies Bldg., N.Y.C.

Present were: Members: H. O. Hill, G. N. Sieger, C. A. Adams, O. B. J. Fraser and H. W. Pierce. Members ex-officio: W. Spraragen, L. M. Dalcher and M. M. Kelly.

Call to Order

The meeting was called to order by Acting Chairman Hill at 10:45 A.M.

Proposed Budget for Fiscal Year Commencing Oct. 1, 1946

The Treasurer stated that in the preparation of this budget, attempt has been made to have expenditures come within anticipated income and, at the same time, not prevent the effective continuance of all SOCIETY activities. Although higher income has been budgeted on membership dues and JOURNAL advertising than was actually received in the past year, it is the feeling in case of membership dues, that the low level has been reached from which growing can be expected, and since JOURNAL advertising has been always the other principal source of income of the SOCIETY, the Finance Committee is hoping the figure proposed for this year can be met. Special mention was made of the following items included in the budget:

Annual Meeting (which is the 1946 Annual Meeting) shows an income of $4200. Check in the amount of $7000 has been received from A.S.M. covering A.W.S. commission on welding exhibit space in the 1946 National Metal Exposition.

It was the consensus of opinion that our SOCIETY had been treated liberally by A.S.M. and that a letter of appreciation should be addressed to the Secretary of A.S.M.

Technical Activities—total expenditures budgeted are less than those of the past year on expectancy there may be a reduction in number of standards published this coming year.

Educational Books—appropriation for publication has been increased to allow for books in the making.

The Treasurer explained that the total overhead, including salaries, rent and the like, is absorbed in the functional items shown at the end of these minutes, such as JOURNAL, Technical Activities, Membership and Sections, Annual Meeting, Handbook, Administration and the like, the distribution being based on salaries paid to and time spent by staff on these functions.

After deliberation, it was, upon motion, duly seconded, voted to approve budget for fiscal year commencing Oct. 1, 1946, recommended by the Finance Committee.

Committee Personnel Changes

Upon motion, duly seconded, the following changes in commitee personnel were approved:

Educational Committee.—Additions: Dr. Finn Jonassen, National Research Council, Washington, D. C. This appointment is made on recommendation of the Educational Committee. Prof. O. H. Henry, Brooklyn Polytechnic Institute, Brooklyn, N. Y. Recommendation of Prof. Henry's appointment was approved at the Directors' meeting on November 22nd but his name was omitted from list of committee personnel attached to minutes of November 22nd Board meeting.

Welding Handbook Committee.—Resignation: W. Spraragen as Advisory Member. Acceptance of this resignation was at Mr. Spraragen's request and with the understanding that President Delhi acquiesced. Addition: On recommendation of the Handbook Committee Chairman, H. O. Klinke was made a member of this Committee.

Rules Governing 1947 RWMA Prize Contest

On recommendation of Mr. Sieger, liaison officer of RWMA, it was voted to accept regulations governing the 1947

American Welding Society Budget for the Fiscal Year Commencing Oct. 1, 1946, Showing Functional Breakdown of Expenses

Income:			
Membership Dues		$101,000.00	
JOURNAL Advertising		60,000.00	
JOURNAL Supplement		4,120.00	
JOURNAL Cuts		2,750.00	
Subscriptions and Sales of JOURNALS		16,400.00	
Annual Meeting		4,200.00	
Codes, Standards and Binders		6,000.00	
Educational Books		5,000.00	
Welding Handbook		4,000.00	
Sundry Salable Matter		2,000.00	
Interest Income		260.00	
TOTAL INCOME			$205,730.00
Expenses:			
JOURNAL—Text Matter and Advertising	$79,848.46		
Technical Activity and Printed Matter	27,417.22		
Membership and Sustaining Member Activities	13,626.58		
Handbook and Educational Books	14,054.70		
Section Activities	9,574.23		
Annual Meeting	9,663.29		
Administration	13,587.52	167,772.00	
Section Refunds	23,000.00		
Sundry Salable Matter	2,000.00		
Purchase of Equipment	750.00		
Adams Lectureship Award	200.00		
Publicity	1,000.00		
Yearbook	2,350.00		
Contingencies	954.20	30,254.20	
Employees Insurance Expense		5,646.50	
1% of Gross Income to be transferred to Permanent Funds Reserve Account		2,057.30	
TOTAL EXPENSES			$205,730.00

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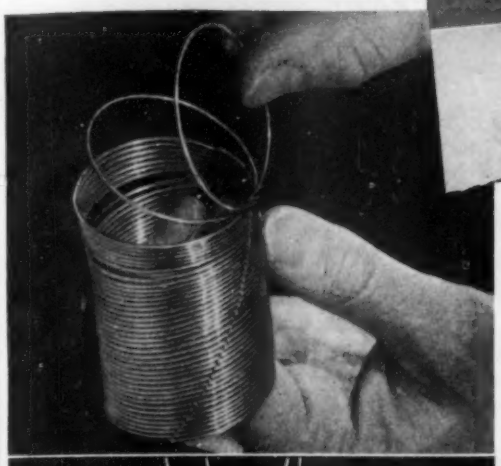

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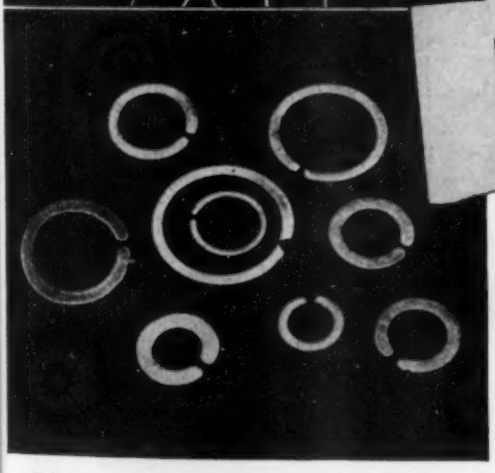

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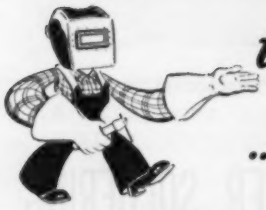

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RWMA Prize Paper Contest, as submitted by the Educational Director of RWMA, with the following modification: "In order to be eligible for this contest all papers must be forwarded so as to be delivered at AMERICAN WELDING SOCIETY headquarters no later than 5:00 P.M., July 31, 1947."

Editor of Third Edition Welding Handbook

Mr. Hill reported, when it was learned definitely it was impossible for Mr. Klinke to sever his present connection with Airco, serious consideration was given to his replacement, so as to avoid undue delay in publication of the *Handbook*. As a result of correspondence and conferences with those concerned with this activity, the best solution appeared to be the placement of the publication of the *Welding Handbook* and other educational books in the Technical Activities Department, with the Technical Secretary as Editor-in-Chief. Such arrangement, it was felt, will provide for coordination of two allied activities and place the technical staff at the services of the Handbook Committee during peak periods when the greatest amount of help is needed, with little or no increase in A.W.S. staff.

After due deliberation, it was voted that publication of the third edition of the *Welding Handbook* be made the responsibility of the Technical Activities Committee under the direction of the Technical Secretary as Editor-in-Chief, and subject to policies established by the *Welding Handbook* Committee; further, that the above proposed arrangement for publication of the *Handbook* be approved officially by the Chairmen of the Technical Activities and *Welding Handbook* Committees.

Progress Report on Separate Welding Show

Mr. Pierce, Chairman of special committee appointed at the Oct. 24, 1946, Board meeting, with scope to investigate and report back on possible arrangement for holding a separate welding exhibit sponsored by A.W.S., reported progress. He stated that work is under way and he is planning to hold a meeting of the committee on December 23rd, with the idea of being prepared to render report to the Directors at their Feb. 14, 1947, meeting. The Secretary was requested to provide for this item on the agenda of the February 14th meeting.

Adjournment

The meeting adjourned at 12:45 P.M.

STRESS AND STRAIN IN PLASTIC FLOW

A comprehensive treatment on the subject of Stress and Strain in Plastic Flow, has been prepared by Captain W. P. Roop of the Model Basin. The pamphlet has been prepared for the benefit of engineers who ordinarily do not think in terms of plastic flow of metals. However, in most welded structures there is some plastic flow. Price 50¢.

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1026

1947 A. W. S. DIRECTORY

In order to conserve paper, the new 1947 A. W. S. Membership Directory, now available, will be sent only to those requesting a copy. There is no charge to members of the SOCIETY. Address request to: American Welding Society, 33 W. 39th St., New York 18, N. Y.

RESISTANCE WELDING RESEARCH

The Resistance Welding Research Committee is one of several important projects sponsored by the Welding Research Council. There are many and diversified problems confronting this branch of the industry. In order to solve these problems, the Welding Research Council has organized a large and eminent Committee known as the Resistance Welding Research Committee. The Council has centralized all of its research activities relating to Resistance Welding into one Committee. A number of definite projects have been formulated. The investigations will be started as soon as sufficient funds are made available to do the work. The total annual cost of this program is estimated to be $42,500. One-third of these funds has been pledged. The Council is now endeavoring to secure the balance. The projects involved in this program are briefly described below.

Projection Welding

Rensselaer Polytechnic Institute, Annual Cost, $6,000

Initial research will be confined to basic fundamental problems including the following:

1. Determination of the optimum size, shape, and proportion of projections and the effect of variation of these factors on weld strength and consistency.
2. Investigation of the proper spacing of multiple projections.
3. A study of minimum edge distances
4. Comparison of the ratio of the strength of multiple to single welds. This is to be done with clusters of two and four welds.

Fatigue of Spot Welds

Franklin Institute, Annual Cost, $15,000

The objectives of this Committee are:

1. To establish a rational basis upon which to obtain and evaluate the stresses, existent or applied, in spot welds and spot-welded structures in relation to "fatigue."
2. To determine ways and means, if possible, of lowering the magnitude of the stresses so found, in relation to fatigue.

Fatigue Strength of Spot Welds

École Polytechnique, Cost $2000

Professor Georges Welter of École Polytechnique has developed some interesting Amelioration Treatments of spot welds which involve the use of high compressive stresses directly after the welding has been performed, sometimes when the weld is still hot, and other times after the weld has been cooled.

Flash Welding

(Laboratories not yet assigned), $10,000

The Committee has under consideration two problems:

1. Temperature measurements during flash welding.
2. Properties and materials at flash welding temperatures.

The purpose of the first investigation is to develop methods of measuring operating temperatures and temperature gradients during flash welding and to bring out the material properties and welding conditions which control the temperature.

The second problem is that of determining the important properties of commonly welded steels, particularly at the elevated temperatures of flash welding. These properties would be the electrical and physical properties on which the temperatures depend and the mechanical properties which become involved in upsetting.

Spot Welding of Mild Steel, Structural Grade, in Thickness of 1/8 in. to 3/4 in.

Rensselaer Polytechnic Institute, Cost, $6000

Previous investigations have established optimum conditions for the spot welding of mild steel in thicknesses up to 1/8 in. Many structural applications are awaiting the establishment of the same type of information for thicknesses of steel ranging from 1/8 to 3/4 in. It is proposed to establish optimum spot welding conditions such as welding current, electrode force weld time, size of spots, etc. for these heavier gages.

Minimum spot weld spacings will be established and the effect of ordinary mill scale on the weld strength and consistency will be studied.

Welding conditions will be evaluated by mechanical testing of the welds which will include shear, tension and impact tests.

Contact Resistance

Johns Hopkins University, $3500

This investigation is of a very fundamental nature seeking to discover the laws governing the phenomenon of electrical contact resistance between the materials to be resistance welded together. This investigation will cover different types of surface conditions and different materials The work will also attempt to discover the laws governing the contact resistance between the electrode and the material as affected by surface finish, composition, shape and form, and temperature of the electrodes. Not only will the laws be studied but, also, the application of the laws governing contact resistance to welding practice. They will be correlated with the properties of welds produced.

INDEX TO ADVERTISERS

Air Products Incorporated	267	Lukens Steel Company	261
Air Reduction Sales	Outside back cover	P. R. Mallory & Co., Inc.	255
American Brass Company	Inside back cover	Marquette Mfg. Co. Inc.	250
American Chain & Cable	253	McKay Company	291
American Optical Co.	281	Metal & Thermit Corporation	Inside front cover
Anti-Borax Compound Company	266	National Carbide Corporation	258
Bastian-Blessing Co.	256	National Cylinder Gas Co.	288 and 289
Champion Rivet Company	265	New Mexico Steel Co.	262
Detroit Stamping Company	260	Page Steel & Wire Division	253
Eisler Engineering Co.	260	The Reid-Avery Company	275
Electroloy Co., Inc.	264	Resistance Welder Mfrs. Association	259
General Electric Co.	263	Sciaky Bros., Inc.	257
Harnischfeger Corp.	272 and 273	Shawinigan Products Corp.	266
Haynes Stellite Company	199	The Sight Feed Generator Company	254
Hobart Brothers Co.	197	Tube Turns Inc.	283
International Nickel Co., Inc.	279	Union Carbide and Carbon Corp.	199, 286 and 287
K-G Welding and Cutting Company	267	Victor Equipment Co.	200
The Lincoln Electric Co.	271	Wall Colmonoy Co.	277
The Linde Air Products Company	286 and 287	War Assets Administration	251
Lucas-Milhaupt Engineering Co.	249	Weltronic Company	269

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THE A. F. DAVIS UNDERGRADUATE WELDING AWARD

To stimulate undergraduate interest in welding, funds have been donated to the AMERICAN WELDING SOCIETY for the A. F. Davis Undergraduate Welding Award. This award will consist of four cash prizes given annually to authors and publications for the best and second best articles on welding published in undergraduate magazines or papers during the preceding year. Any undergraduate of a college or university in the United States or Canada is eligible, but the paper must be published in an undergraduate publication.

The A. F. Davis Undergraduate Welding Award is named for its donor, A. F. Davis, vice-president and secretary of the Lincoln Electric Co., Cleveland, Ohio.

FLASH WELDING BOOK

A translation of the most comprehensive book yet available on flash welding. The book is available as a separate pamphlet of 55 pages, JOURNAL size, copiously illustrated. Price $1.00.

Order copies through the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

ARC WELDING INSPECTION HANDBOOK

This 156-page handbook is the most complete and authoritative manual that has yet been published on the subject of welding inspection. It covers requirements for a welding inspector, duties of a welding inspector, methods of testing welds and a comprehensive description of weld inspection by visual, magnetic particle and radiographic methods. One section of the handbook discusses the principal types of weld defects and indicates how they may be detected and corrected. The entire book is written in simple language and is intended to serve as a reliable source of information on any welding inspection problem.

Copies of the Inspection Handbook for Manual Metal-Arc Welding may be obtained from the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y., at $1.50 per copy.

ADAMS LECTURE SERIES

In honor of its first President and Founder the AMERICAN WELDING SOCIETY created an honorary scientific lecture series known as the Adams Lecture. Each year the lecture is awarded to some outstanding meritorious scientist or engineer. The reports have been issued in attractive pamphlet form and are available at 50¢ each. They are as follows: 1944—Solid Phase Welding, by A. B. Kinzel; 1945—Selection of Steel for Welding, by S. L. Hoyt; 1946—New Frontiers in Welding, by Wendell F. Hess.

ENGINEERING FOUNDATION ASKS BEQUESTS AND GIFTS TO AID RESEARCH PROJECTS IN ENGINEERING

Dr. A. B. Kinzel, Chairman of the Engineering Foundation, Engineering Societies Building, 29 West 39th St., New York, N. Y., has announced that in view of the postwar increase in opportunities for productive research in the field of engineering, the Foundation would welcome bequests and gifts to supplement its current principal fund of about $1,000,000.

The Foundation has been engaged in important research activities for more than 30 years. It was created by the four Founder Societies in the engineering field —American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society

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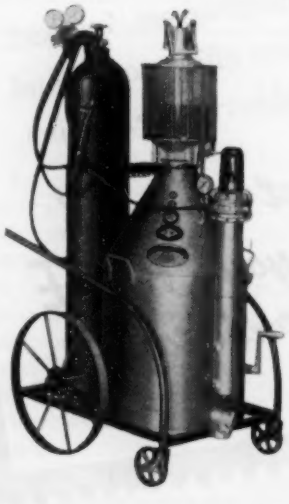

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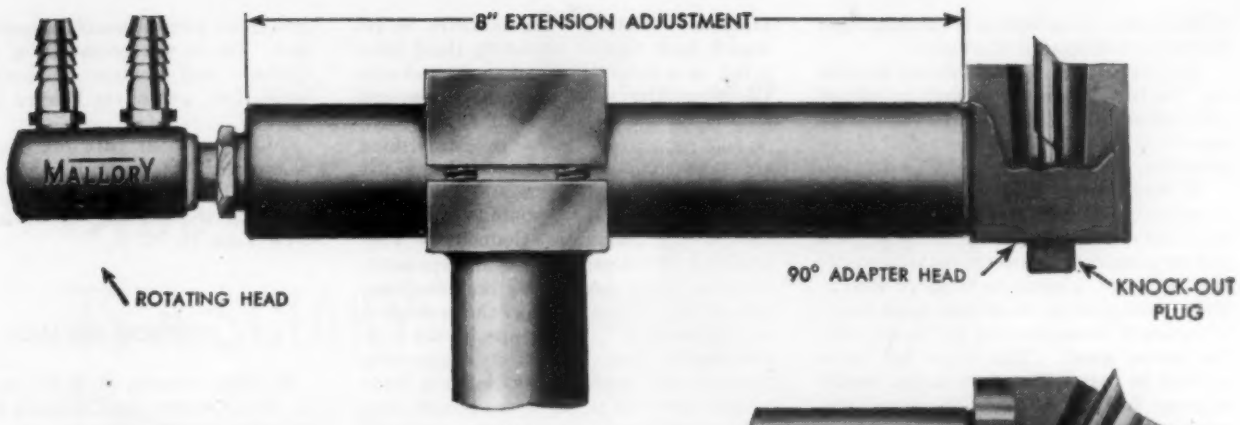
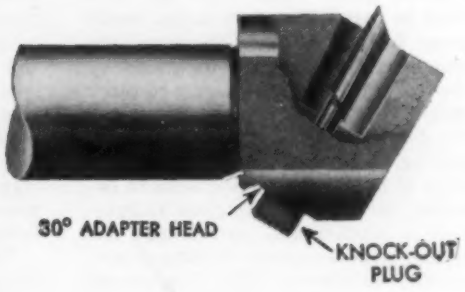




HEAVY DUTY HOLDERS
Are Stock Items
at RESISTANCE WELDING ELECTRODE HEADQUARTERS

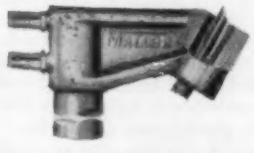
. . . and they're made of the finest copper alloys!

(R.W.M.A. Group A, Class II and Class III)

A complete line of standardized heavy duty holders that will meet most of your requirements is carried in stock. Universal type adjustable holders with 90° or 30° easily changed heads are available along with heavy duty offset holders having 90° or 30° heads. There are exceptions where special platen type holders are needed to fit individual machines for high pressure work. Mallory engineers are available to design such holders for your special needs.

A heavy duty offset ejector holder with 90° head available in 2" and 4" offset.

Mallory heavy duty holders, in addition to saving you the extra time and expense of making special setups, offer other unusual features. They have a special knockout device, for instance, that easily removes electrodes "driven in" by high pressure operations. The Universal holder illustrated has a 90° or a 30° head adapter which may be quickly changed for a new setup. These holders also may be easily adjusted for various lengths of offset merely by loosening the bolts in the "T" connection. What's more, the holders (the adapter and "T" connections, too) are made of R.W.M.A. classification copper alloys that insure excellent strength and high electrical conductivity.



A heavy duty offset ejector holder with 30° head available in 2" offset.

Send for a free copy of the Mallory Electrode and Holder Catalog. It will save you time and money.

In the United Kingdom, made and sold by MALLORY METALLURGICAL PRODUCTS, LTD. (An Associate Company of Johnson, Matthey & Co., Limited), Hatton Garden, London, E. C. 1.

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*REG. U. S. PAT. OFF.

RESISTANCE WELDING MATERIALS

of Mechanical Engineers and the American Institute of Electrical Engineers.

The Foundation was established in 1914 for "the furtherance of research in science and engineering, and the advancement in any other manner of the profession of engineering, and the good of mankind."

"It was hoped," said Dr. Kinzel, "that a great 'community trust' for engineers might be contributed to by many persons and organizations, thereby making available sufficient income to support worthwhile investigations to advance fundamental research in engineering and promoting the public good. This hope has been realized in part. The Foundation would welcome further gifts and bequests, the income from which could be used to carry on or to aid carefully chosen research projects."

The Foundation assists in originating, organizing, financing and the following through of projects in diverse fields of engineering, preference being given to projects of a fundamental nature and not competing with research in the laboratories of various industries. The Foundation supplements research activities carried on at the universities, by engineering and scientific societies and by industrial laboratories.

"The Foundation's sponsorship and financial support of a research project most commonly stimulates or enables the obtaining of additional and frequently much larger contributions of money, material and services from institutions, industry and individuals," Dr. Kinzel explained. "While its expenditures in research have totaled $635,600, these have acted as a catalytic agent or stimulus to the expenditures on researches sponsored by the Foundation to about $5,000,000."

The foundation aided in establishing the National Research Council and its Division of Engineering and Industrial Research. It has contributed to the support of the Engineers' Council for Professional Development, which, representing some eight engineering organizations, aims at the advancement of the profession of engineering. More specifically the Foundation has supported engineering research and investigations in such fields as arch dams for power development, etc., soil mechanics and foundations, arch and column design, hydraulic research, thermal properties of steam, welding, stability of steels as affected by temperature, plastic flow of metal, alloys of iron, metal cutting, cotton seed processing, di-electrics and power cable insulation and many other fields.

The Foundation is a department of the United Engineering Trustees, Inc., a non-profit organization exempt from Federal income tax. Contributions made to the United Engineering Trustees, Inc., for the Engineering Foundation Fund, are deductible for Federal income tax purposes to the extent provided by the Act. The Foundation is administered by a Board of 16 members, including men outstanding in the engineering profession, research, business and education.

Dr. Kinzel, Chairman of the Foundation, is an internationally known metallurgist. He is vice-president of the Union Carbide and Carbon Research Laboratories, Inc., and of the Electro Metallurgical Co.

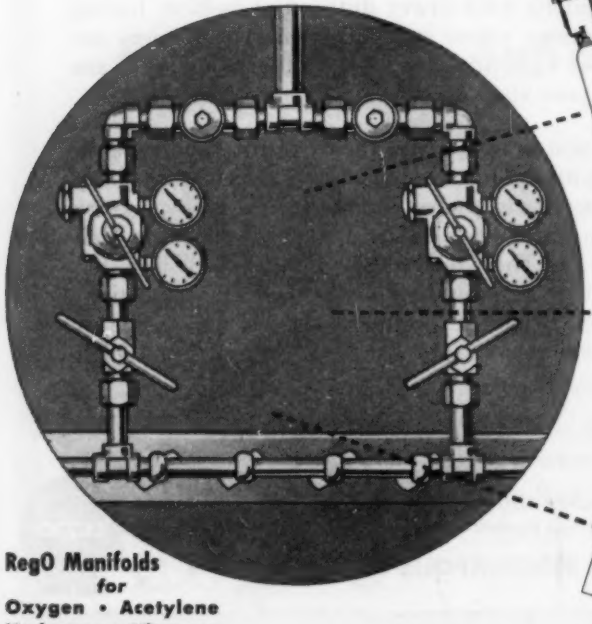
Inquiries about gifts and bequests may be directed to John H. R. Arms, Secretary of the Engineering Foundation, Engineering Societies Building, 29 West 39th St., New York 18, N. Y.

OSTROM EXPANDS

K. Wm. Ostrom (A.W.S.), president of K. Wm. Ostrom and Company Resistance Welding Service, recently announced the establishment of new office and warehouse facilities at 1525 Wood St., Philadelphia 2, Pa.

The Company is primarily agent for National Electric Welding Machines Co. and distributor for P. R. Mallory and Co., but has expanded its line to present a complete resistance welding service including machinery, electrodes, forgings, castings, special fixtures and controls as well as miscellaneous machine parts. Their activities also include a repair service for equipment with the thought that there be no need for any resistance welder in the Philadelphia area to remain out of production for any length of time.

Henry A. Young (A.W.S.) is vice-president and treasurer of the Company with Michael J. Bonowitz (A.W.S.) in charge of service and repair.



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for
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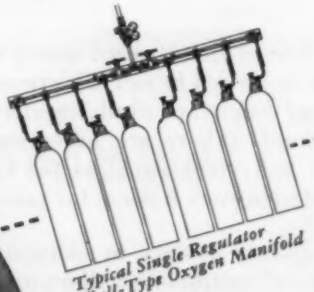
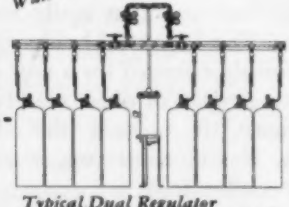
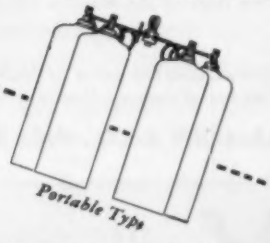
Hydrogen • Nitrogen
and other high
pressure gases



Typical Single Regulator Wall-Type Oxygen Manifold



Typical Dual Regulator Floor-Type Acetylene Manifold



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CONSTRUCTION
PRODUCES BETTER
MANIFOLDS

● RegO design means safe performance, long life and low maintenance costs. Here are some of the construction features you get when you specify RegO Manifolds...

Unit Construction... The header section of each RegO Manifold is virtually one-piece; extra-heavy seamless brass pipe is run through the forged brass header fittings, the cylinder station shut-off valves and the master shut-off valves...all permanent connections are then silver-brazed. The header assembly is bolted to a heavy steel I-beam to assure permanent alignment.

Precision Regulation... large capacity two-stage RegOlators assure constant and uniform delivery pressure to the pipe system.

Extra Convenience... standard RegO Manifold construction provides individual shut-off valves at each cylinder station...this design permits any one cylinder to be disconnected without shutting down the entire manifold. Master shut-off valves control each main branch.

Rigid Tests... header pipe, valve bodies and fittings withstand pressure up to 10,000 psi and each complete RegO Manifold is subjected to a sustained air pressure test up to 2,000 psi.

There Is A RegO Manifold to Fit Your Most Exacting Requirements

The BASTIAN-BLESSING Company
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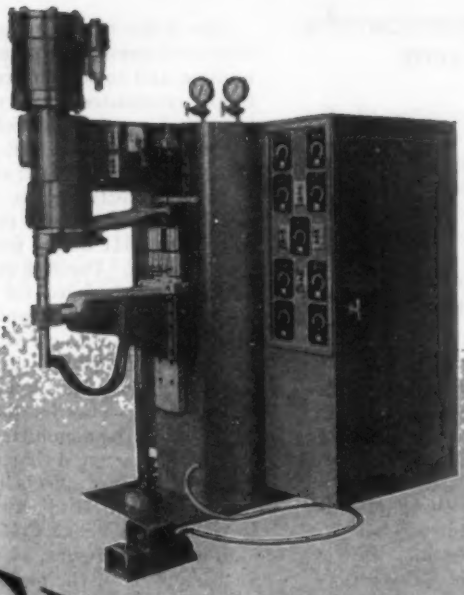
Pioneer and Leader in the Design and Manufacture of Precision Equipment For Using and Controlling High Pressure Gases



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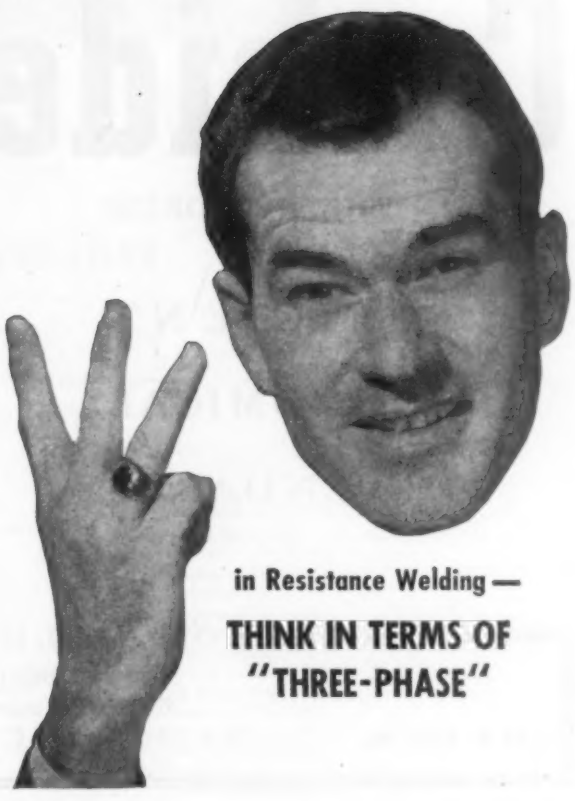


in Resistance Welding —

THINK IN TERMS OF "THREE-PHASE"

A.S.M.E. BOILER CONSTRUCTION CODE SEC. VIII REDRAFTED

The Boiler Code Committee of The American Society of Mechanical Engineers announces that its special committee to revise Section VIII of the A.S.M.E. Boiler Construction Code (Unfired Pressure Vessel Code) has just completed its work and has submitted a report to the Boiler Code Committee in draft form as a proposed revision of Section VIII, dated January 1947.

One of the outstanding features of the new draft is the development of a more logical arrangement of material, which closely follows that in the A.P.I.-A.S.M.E. Unfired Pressure Vessel Code. The basic minimum requirements are essentially those established in the alternate rules for unfired pressure vessels, issued as a part of the 1944 addenda to the code. Besides improved arrangement, the proposed revision embodies the following additional features: (1) Improved and extended rules for the design of formed heads under internal and external pressure; (2) provision for the design of cylindrical shells under external pressure at elevated temperature; (3) joint efficiency for fusion-welded vessels established on a premium basis; (4) spot examination of fusion-welded vessels as a minimum requirement; (5) incorporation of a nonmandatory appendix as a guide for the inspection of vessels in service.

The Boiler Code Committee invites all interested persons to review the proposed revision and to submit comments thereon to the committee. The new draft is obtainable from J. W. Shields, secretary of the committee, A.S.M.E., 29 West 39th St., New York 18, N. Y., at $1.00 per copy.

The committee plans to hold several public hearings on the proposed revision of Section VIII before final consideration for adoption. The first hearing has been tentatively scheduled for Houston, Tex., on May 1, to be followed by another in Los Angeles, Calif., on May 7. Those interested are invited to attend and to participate. Further information concerning these hearings may be obtained from the secretary of the committee.

It should be noted that the proposed revision in no way affects the forthcoming issuance of the 1946 edition of the Unfired Pressure Vessel Code. There is no indication at present as to the date of final adoption of the proposed revision.

PROGRESSIVE MEMBERSHIP REACHES 50

Five additional new memberships in the AMERICAN WELDING SOCIETY make the total memberships of the Progressive Welder Co., 3050 E. Outer Dr., Detroit, Mich., reach the half century mark (50). Congratulations!

223-TON STEEL VESSEL FOR TESTING HIGH-PRESSURE UNDER-WATER EQUIPMENT

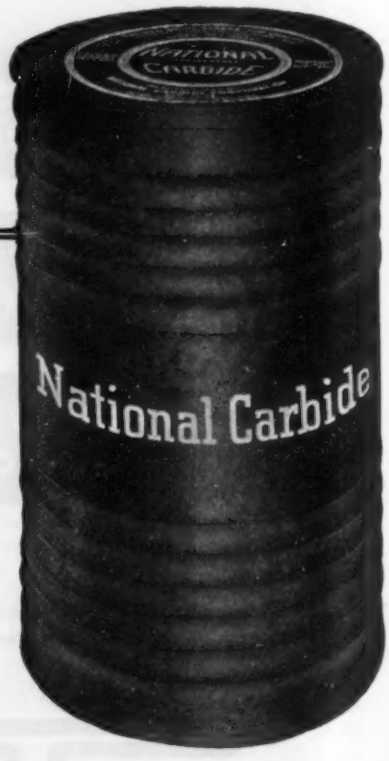
A contract for the construction of a 223-ton steel pressure vessel to be used in testing underwater equipment at the new Naval Ordnance Laboratory at White Oak, Md., has been awarded to The Babcock & Wilcox Co., Barberton, Ohio, by the Charles H. Tompkins Co., of Washington, D. C., officials of the boiler company announced recently.

The vessel is a cylindrical drum, 30 ft. long, with an inside diameter of 100 in. and a shell thickness of $3^{15}/_{16}$ in. It will be made of steel with an ultimate tensile strength of 70,000 psi. and have a working pressure in the drum of 1000 psi. It will be possible to open one entire end of the drum by means of a large quick-opening door. This door will close against a ring that will be welded to the outside of the cylinder and must be able to seal against 1000-lb. operating pressure and withstand a test pressure of 2000 psi.

Three windows of heavy pyrex glass will allow observation of the interior while testing is taking place. The drum is designed to simulate either underwater or atmospheric pressure, but will probably be used mostly for the former. It is expected that certain submarine apparatus and instruments which are exposed to water pressure, as well as other high-pressure underwater equipment, such as divers' suits, will be tested in this vessel.

National
Carbide
IN THE RED DRUM

EFFICIENT
ECONOMICAL
DEPENDABLE



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Write us for information as to nearest available stock.
60 E. 42nd St. NATIONAL CARBIDE CORPORATION New York 17, N. Y.

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RESISTANCE WELDING MANUAL

(REVISED EDITION)

Complete ✓ ✓ ✓ Comprehensive ✓ ✓ ✓ Authoritative

FACTS

1. This new manual is the most complete treatise on resistance welding ever published. It explains in detail what resistance welding is, what it does, and how to use it.

2. Resistance welding is the quickest and most economical known method of fabricating metals.

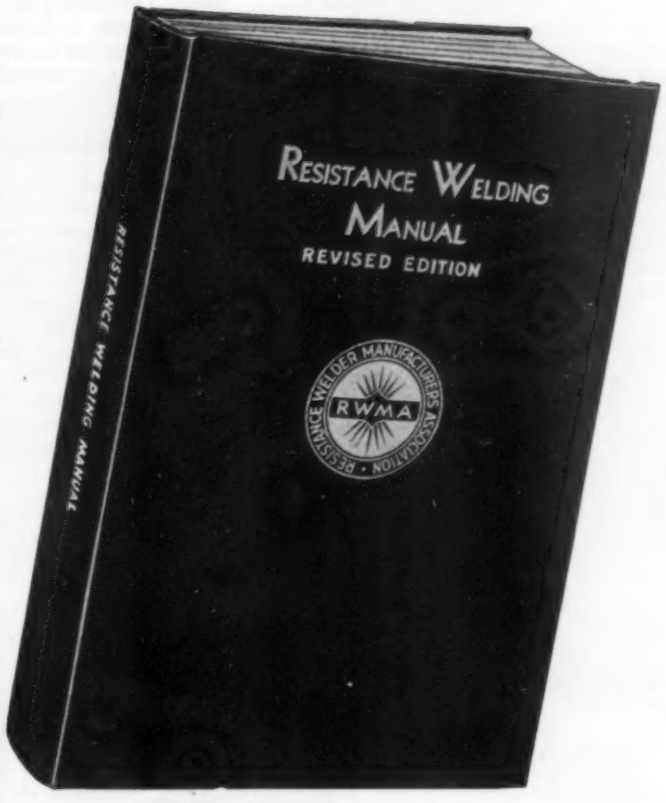
CONCLUSION

If you make metal articles, or if you are an engineer, student or teacher—

YOU NEED THIS BOOK

CONTENTS

Fundamentals — Applications — Economics — Design for Welding — Electrodes — Wheels — Dies Process Control — Maintenance — Spot, Seam, Flash, Projection Welding — Pulsation Welding — Percussive Welding — Electro Brazing — Electro Forging — Low Carbon Steel — Hardenable Steels — Stainless Steel — Coated Steels — Aluminum — Copper, Magnesium & Nickel Alloys — Lead — Die Castings — Dissimilar Metals — Recommended Practices — A. C. Machines — Stored Energy Systems — Jigs and Fixtures — Controls — Electrical Characteristics — Power Supply — Instrumentation — Standard Tests and Quality Controls — Maintenance — Definitions — Symbols — Tables.



PRICE $3.00

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Detroit 4, Michigan
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Detroit 13, Michigan
Welding Sales & Engineering Co.
Detroit 13, Michigan

Following the welding of the plate steel which forms the shell, all seams will be inspected by 1,000,000-v. X-ray equipment and the vessel stress relieved. It will be fabricated as a Class I pressure vessel, meeting all code requirements of The American Society of Mechanical Engineers. The ring and door will be attached at Barberton and pressure tests made. The shell will be shipped to Maryland as a unit. It is estimated that from eight to nine months will be needed to build the vessel.

The door, forming the end of the shell, will be an extremely large casting. It will be made for The Babcock & Wilcox Co. by the Adamson United Co. of Akron, a company specializing in tight-sealing doors. The ring, against which the door will close, will also be cast by the Adamson Co. The ring and door combined are so large that they will create a shipping problem and special arrangements are now being made for rail and truck transportation.

The vessel was designed to Navy specifications by The Babcock & Wilcox Co. in conjunction with the Adamson United Co.

N. J. WEISS ASSOCIATES

Nat J. Weiss, Sales Manager for the past five years of the Larkin Lectro Products Corp., has formed the Nat J. Weiss Sales Associates which will handle all sales, domestic and foreign, of the entire output of the Larkin Co. These include not only a complete line of spot, projection, butt and special resistance welding units, but also a well rounded line of A.-C. Stepless Microamp Control.

H. R. E. (Ed) Austin, formerly Sales Manager with Rex Welder & Engineering Co., and District Manager with the National Cylinder Gas Co., will be associated with the new organization.

Nat J. Weiss Sales Associates will be located at the plant of the Larkin Lectro Products Corp., 160 W. 146th St., New York, N. Y. Telephone: Edgecombe 4-7907.

Nat Weiss is a member of the New Jersey Division, A.W.S., and Mr. Austin was formerly a director in the Kansas City Section and is now transferring to the New York City Section.

SUSTAINING COMPANY

Wyman-Gordon Co., Worcester 1, Mass. —From loom and bicycle parts in 1883, to today's high quality, alloy steel and light metal aircraft forgings, the Wyman-Gordon Co. has led in the development and adaptation of new techniques.

A recent development has been the application of pressure welding to forged aircraft parts. Propeller hubs, presently being manufactured in this manner, provide substantial savings in weight and machining over conventional methods.

Through constant research, Wyman-Gordon will continue to provide the automotive and aircraft industries with superior forgings.

STAINLESS-CLAD STEEL

Manufacture of a complete line of Stainless-Clad Steels has been announced by Lukens Steel Co. of Coatesville, Pa.

Seventeen years ago, Lukens Steel Co. began the production of its first clad metal—Nickel-Clad Steel. Other clad steels, Inconel-Clad and Monel-Clad Steel, were later developed by Lukens.

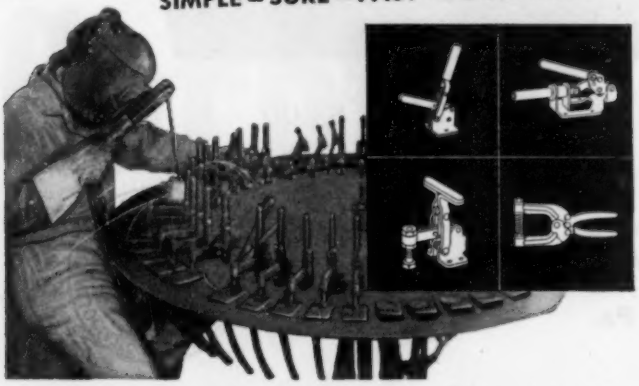
In the Lukens' method of manufacturing Stainless-Clad Steels, a light layer of the proper type of solid stainless steel is bonded to a backing plate of carbon- or low-alloy steel. The Lukens' process insures uniformity of cladding thickness and a permanent bond between the stainless steel and the backing plate.

Stainless steels of types 304, 316, 347, 410 and 430 are the cladding materials generally used. They offer the corrosion resistance and product protection of solid stainless steel, at appreciable savings in material cost over solid stainless. In addition, they have far superior heat conductivity than solid stainless steels and are readily fabricated.

Lukens Stainless-Clad Steels exceed the minimum shear strength requirements of the A.S.M.E. Code of 20,000 psi. The A.S.M.E. Code permits the cladding to be included in the full thickness for many applications. The cladding is usually 10% of total plate thickness, although any percentage from 5% up to 50% can be obtained. Specifications of both the stainless and the backing plate may be widely varied to meet chemical and physical requirements.

SMART TOOLING!

SIMPLE – SURE – FAST – FOOLPROOF



Here's efficient tooling based on the quick action and positive holding power of De-Sta-Co Toggle Clamps. This simple turntable with its 48 No. 210-S clamps enables one welder to keep abreast of two helpers. One places curved shank in socket and unloads finished assemblies. The other locates pierced hole in plate over shank and locks securely with toggle clamp. The expert welder works without interruption.

Smart tooling like this is the backbone of modern mass-production technique. You'll see De-Sta-Co Toggle Clamps playing vital parts *wherever* the principles of sound tool engineering are observed. Welding production is *only one* of the many fields for quick acting clamps. For holding parts in milling, drilling, routing, riveting, cementing—for fast, uniform, *foolproof* action—progressive tooling demands De-Sta-Co adaptability and quality. There's a De-Sta-Co clamp for every job, designed and built to stand up under the wear and tear of volume production. Send for copy of Catalog No. 47.

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SPOT • BUTT • ARC WELDERS

AIR, FOOT or MOTOR Operated Press Type Welders of All Sizes.

We manufacture a complete line of resistance spot welders from ¼ to 300 KVA for all types of welding. There is an EISLER WELDER for every purpose.

Transformers of all types.

We invite contract spot welding in large or small quantities.

Write for Catalog

EISLER ENGINEERING CO.

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Here's why UNIFORM THICKNESS *OF STAINLESS CLADDING is assured*

Hot rolling Lukens Stainless-Clad Steel on the 206" Mill, world's largest plate mill. In this operation, the stainless steel and the backing plate are permanently and uniformly bonded.

This picture shows a solid stainless steel insert being placed on a carbon steel backing plate – one of the assembly steps, preparatory to hot rolling, in the production of Lukens Stainless-Clad Steels. The thickness of each component has been pre-determined to assure the required uniform percentage of cladding to total plate thickness in the finished clad steel plate.

Precision assembly and the high, uniform rolling pressure, employed to reduce and bond the components, give positive control over the uniformity of cladding thickness. There's no guesswork about it!

Lukens Stainless-Clad Steels are usually furnished in 10% or 20% clad, but percentages from 5% to 50% can be produced.

Any standard specification stainless, including types 410, 430, 304, 316, 347 and others, can be supplied in plates from 3/16" to over 3" thick, or up to 162" wide; also in formed heads in all styles and sizes to over 18' in diameter.

Beginning with Nickel-Clad Steel 17 years ago, Lukens now manufactures a complete line of clad steels produced by the same process. Each of these clad steels offers the corrosion resistance and product protection of the solid metal at substantial savings in cost.

★

Additional information on Lukens Stainless-Clad Steels is offered in the new Bulletin 338; on Lukens Nickel-Clad, Inconel-Clad and Monel-Clad Steels in Bulletin 255. Copies of these Bulletins will be sent on request.

★

LUKENS
Nickel-Clad Stainless-Clad
Inconel-Clad Monel-Clad
STEELS
★

LUKENS STEEL COMPANY
World's Largest Plate Mill
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Cable Address: Lukens

Lukens Stainless-Clad Steels are furnished in plates from $^3/_{16}$ in. to over 3 in. thick; or up to 162 in. wide; and also in heads of all styles and sizes to over 18 ft. in diameter.

Lukens Stainless-Clad Steels are expected to have wide use in equipment for processing food products, paper, petroleum, pharmaceutical, synthetic resins and plastics, and organic compounds as well as for equipment handling chemicals, such as sulphuric, nitric and mixed acids.

FABRICATING ALUMINUM

To meet the insistent growing demand for more technical information on fabricating and processing aluminum in all its forms, Reynolds Metals Co. has inaugurated a new service to the metalworking industries by establishing the "Technical Advisor," a monthly technical paper devoted to publicizing latest recommendations on how to use aluminum mill products most effectively.

The first issue, just published, carries a condensed technical description of the two main processes in the production of aluminum—the Bayer process of producing alumina from bauxite, and the Hall process for reducing alumina to metallic aluminum.

A question-and-answer section is dedicated to making available to a wider audience the answers to many questions sent in to Reynolds technical men. This first issue contains a discussion of various problems in connection with the use of aluminum in a mink waterer, portable kitchens, newspaper delivery tubes, buckets, sofa bed frames; "colors" of various alloys; and the soldering of aluminum.

An outstanding feature of the publication is the technical process studies included serially. The current series is devoted to the welding of aluminum, with this first issue covering the general factors involved, weldability of the various aluminum alloys, application of gas welding, edge preparation for gas welding.

The periodical is sent free upon request to Technical Editorial Service, Reynolds Metals Co., 2500 S. Third St., Louisville 1, Ky.

AMERICAN STANDARDS

A list of 864 standards approved for national use of industry by the American Standards Association has been made public and is available for general distribution, P. G. Agnew, vice-president of the Association, recently announced.

"The revised list of standards, which includes many of those developed under war procedure and now approved for peacetime use, will be made available to interested trade, technical and governmental bodies and individuals without charge," Dr. Agnew said.

The standards listed include definitions of technical terms, specifications for metals and other materials, methods of work and methods of test for finished products. They reach into every important engineering field. They also include standards dealing with public and industrial safety, industrial medicine and a wide variety of consumer goods.

"Many of the standards have a particular interest to lawyers, legislators and public regulatory authorities because they form the basis for municipal, state and federal regulations," Dr. Agnew said.

"These standards represent agreement on the part of maker, seller, user and regulatory groups as to the best possible practice at the time of approval," he declared. "They are revised periodically to keep up with mechanical invention, developments of power and new uses for materials."

This list, as shown by A.S.A. records, represents the cumulative efforts of about 3000 men, representing 660 organizations working on the development of standards.

WROUGHT IRON STORAGE TANKS

Two wrought iron storage tanks which served for more than 50 years in the Findlay fields of the Ohio Oil Co., but had been previously used in Pennsylvania by the Buckeye Pipe Line Co., have been purchased by the Dow Chemical Co., dismantled, shipped to Marysville, Mich., and the plates used in construction of a new all-welded tank.

Representatives of the Austin Co., Midland, Mich., which handled the project for Dow Chemical, reported that the iron plates do not show any appreciable damage, although it had been so long since they were painted that it was difficult to find any paint remaining on the metal surface. The tank bottoms evidently had never been painted.

The tanks are believed to have been of 7-ring construction, 35,000-barrel capacity, when first used, but when shipped to Ohio the top or seventh ring was removed. They were approximately 85 ft. in diameter, and 25 to 27 ft. in shell height. The first ring is believed to have been composed of $^3/_8$-in. plate; second and perhaps the third rings, $^5/_{16}$ in.; and the remaining rings and bottoms, $^1/_4$ in.

When moved to Ohio in the booming 1890's the tanks were used primarily for storage of the old Lima crude, which was then at peak flow, it is said. Following depletion of the Lima field, crudes were moved in by pipe line, first from Illinois and later from the Mid-Continent fields, and stored in these tanks.

STRESS ANALYSIS MEETING

The Annual Meeting of the Society for Experimental Stress Analysis including a Symposium on Shock and Impact will be held at The Stevens Hotel, Chicago, Ill., on May 15–17, 1947. Inquiries should be addressed to the Society for Experimental Stress Analysis, P. O. Box 168, Cambridge 39, Mass.

Two Wrought Iron Storage Tanks

TIP CLEANING **DRILLS**

Mounted in Knurled

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If your welding involves any of the above metals, you'll want a copy of bulletin GEA-4704 . . . tells the how and what of Inert-Arc welding.

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STUD WELDING DATA BOOK AND CATALOG ANNOUNCED

Designed to provide factual information on the use of automatic stud welding, a new 36-page data book and catalog has been published by Nelson Sales Corp. at Lorain, Ohio.

The Nelson automatic stud welding process, equipment and studs are fully described and illustrated. Complete information on designing for stud welding is given, together with full specifications and physical properties data on Nelson flux-filled studs. A final section of the book is devoted to a description of typical stud welding applications in automotive, contracting and construction, boiler and tank, railroad, electrical equipment manufacturing and general metal-working fields.

Copies of the new Nelson catalog may be obtained from Nelson Sales Corp., Lorain, Ohio.

RESISTANCE WELDING MANUAL—REVISED EDITION

Revisions in this manual of the resistance welding processes have practically doubled the size of the volume compared with the first edition, making the present edition a much more complete treatise. Twenty entirely new chapters have been added. The tables of recommended procedures have been revised to bring them up-to-date with respect to present-day practice. Numerous additions, based upon research and experimental work conducted during the war production period, furnish operating data on materials not covered in previous editions.

In the section dealing with resistance welding procedures, each group of metals is treated in a separate chapter. The general plan of each of these chapters is a discussion of the resistance welding properties of the subject material, followed by explanations of the relative importance of the various operating variables and schedules of recommended welding conditions.

Mechanical and electrical characteristics of both conventional a. c. and stored energy systems are treated in detail, with large additions to the discussions of electrical controls and power supply.

A new section contains chapters on quality control, standard tests and instrumentation. In addition to outlining test specimen requirements for the various standard tests, there is a supplementary discussion which points out the common fields of application for the different methods of testing. Among other important contributions to this edition is a chapter on recommended maintenance practices for resistance welding machines, a glossary of the latest approved definitions used in the industry, and a collection of useful tables.

In the preface of this volume, it is stated that the results of many important research studies have been briefed and abstracted for insertion in proper locations, and that many leading authorities in the welding industry have made valuable contributions of up-to-date information on practices and procedures. In view of the broad scope of the subject matter, this is a resistance welding book which will meet the information requirements of engineers, production executives and machine operators.

Published by Resistance Welder Manufacturers' Association, 505 Arch St., Philadelphia 6, Pa.; 552 pages, 6 x 9 in., cloth bound; $3.00 postpaid.

WELDING FLUX

War Assets Administration has 122,600 pounds of an automatic electric welding flux for sale. This item is in new and excellent conditions and packed in 100-pound bags.

For further details contact Chemical Sections, War Assets Administration, 31 Van Ness Ave., San Francisco 2, Calif.

FREE PAMPHLET ON STORAGE OF MICROFILMS, SHEET FILMS AND PRINTS OFFERED BY KODAK

To aid business and industrial organizations, as well as photographic concerns, to solve the problems connected with the storage of photographic films and prints, the Eastman Kodak Co. has issued a new, free pamphlet entitled, "Storage of Microfilms, Sheet Films and Prints."

Intended to serve as a guide to those who desire to store safety film base and paper base materials only—nitrate films are not covered—the pamphlet discusses the protection required, classification of records, short term storage, archival storage, moderate-term storage, preparation for storage, fire protection, storage relative humidity, storage temperature, and methods of testing the film and papers for hypo elimination.

All suggestions and recommendations in the text are based on extensive laboratory tests and years of experience, and are made with the desire to help preserve valuable photographic records so that they will not only be readily available but also maintained in the best possible condition.

The pamphlet, "Storage of Microfilms, Sheet Films and Prints," may be obtained without charge by writing Sales Service Division, Eastman Kodak Co., Rochester 4, N. Y.

WELDING AND CUTTING CATALOG

Wall Chemicals Division of The Liquid Carbonic Corp. announces its new revised catalog of Gasweld Welding and Cutting Equipment and Supplies.

The catalog features Gasweld's welding and cutting torches, single stage regulators, welding and cutting outfits, and a variety of special purpose torches, tools and accessories.

For copies of the new catalog, write to Wall Chemicals Division of The Liquid Carbonic Corp., 1454 W. Randolph St., Chicago 7, Ill.

ACCIDENT PREVENTION

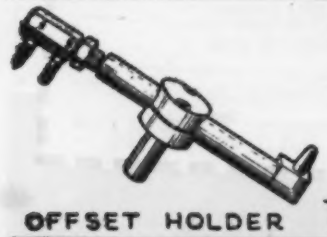
After two and a half years of research and preparation, the National Safety Council has published its new "Accident Prevention Manual for Industrial Operations," which the Council believes is the most comprehensive treatment of the fundamentals of safety available in one volume.

The 544-page manual, containing illustrations, charts and tabulations, is intended as a handy and authoritative source of accident prevention information for safety directors, safety engineers and foremen. Each of the fourteen major divisions of the book is preceded by a summarizing index for quick location of general topics, while a twelve-page detailed alphabetical index at the back gives access to details.

Although prepared primarily for the manufacturing industries, much of the information is applicable to nonmanufacturing industries and to those with industrial operations, such as railroads and ship operators. Insurance engineers will find it a prolific source of information.

The fourteen major subjects covered are: Plant design and layout, construction and demolition, permanent equipment and facilities, guarding and operating machinery, materials handling and storage, electrical hazards, chemical hazards, fire and explosion hazards, flammable liquids, hand and portable power tools, commercial vehicle operation, personal protective equipment, industrial hygiene, and safety organizations and programs.

The manual is available to both mem-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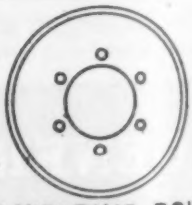
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MONTREAL CANADIENS—Holders of the STANLEY CUP—emblematic of world supremacy in ice hockey.

A team of *Champion Welding Electrodes*, like a team of champion athletes, is dependable, versatile, rugged and fast. In all positions uniform performance and stamina contribute to that perfect co-ordination which licks the toughest jobs and scores a hit with the customers. For consistently top notch results on your welding problems remember "They Have to be Good to be CHAMPIONS."

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CLEVELAND, OHIO — EAST CHICAGO, IND.

bers and nonmembers of the Council. Further information may be obtained by writing the National Safety Council, 20 North Wacker Dr., Chicago 6, Ill.

METALLURGICAL ENGINEERS, INC.

Harry Czyzewski and Dr. David B. Charlton have established Metallurgical Engineers, Inc., in Portland, Ore. This organization will provide testing, consulting, design and development of metal products and processes for manufacturers in the Pacific Northwest.

Harry Czyzewski (A.W.S.) was formerly staff metallurgist in the research department of the Caterpillar Tractor Co., Peoria, Ill.

Dr. Davis B. Charlton is the owner of Charlton Laboratories, Portland.

O. B. J. FRASER APPOINTED ASSISTANT MANAGER OF INCO DEVELOPMENT AND RESEARCH DIVISION

Appointment of O. B. J. Fraser as Assistant Manager of the Development and Research Division of the International Nickel Co. is announced by Robert C. Stanley, president. He succeeds H. J. French, who recently was made assistant vice-president of the company.

For the past thirteen years Mr. Fraser has been Director of Technical Service on International Nickel's Mill Products, and since March 1945, he has also headed the Industrial Chemicals Section of the Development and Research Division in New York. Mr. Fraser for some years has been directing International Nickel's investigational work at Mellon Institute of Industrial Research, Pittsburgh, Pa., on certain problems in the chemistry and technology of nickel.

He joined the company in July 1917, as metallurgical engineer at the Bayonne, N. J., works. In April 1918, he was transferred to the company's Port Colborne, Ontario, works and became successively superintendent of the Electrostatic Fume Precipitation Plant, night works superintendent and research engineer. During

O. B. J. Fraser

1922, while still with the company, he became associated with the Mellon Institute in the study of corrosion of nickel and nickel alloys. Mr. Fraser was placed in charge of the Research Laboratories of INCO at Bayonne in 1924, remaining in that position until 1932. During the next two years he carried on field development work in the use of nickel alloys in the petroleum industry. His first contact with the Canadian nickel industry was in 1914 in exploration work in the Sudbury, Ontario, nickel district at the Levack Mine.

Born in Brookville, Ontario, he received a B.Sc. degree in metallurgical engineering in 1916 from Queen's University, Kingston. During World War I, Mr. Fraser served in the Canadian Field Artillery and was an inspector of military explosives in Canada for the Imperial Ministry of Munitions of Great Britain.

Mr. Fraser is actively identified as both officer and member of committees of a number of metallurgical and engineering organizations. He is National Treasurer of the AMERICAN WELDING SOCIETY, vice-chairman of the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, and a member of American Society of Mechanical Engineers, American Institute of Chemical Engineers, American Chemical Society, Electrochemical Society, American Petroleum Institute (Technical Section), American Gas Association (Technical Section), Electroplaters and Depositors Technical Society, American Society for Metals, American Society for Testing Materials, American Association for the Advancement of Science and Electrodepositors Technical Society of London. He is author of several technical publications.

WALLNER WELDING SUPPLY COMPANY APPOINTED LINCOLN DEALER

W. R. Persons, sales manager of The Lincoln Electric Co., Cleveland, Ohio, announces the appointment of the Wallner Welding Supply Co. as their dealer in Duluth, Minn. The new dealer will be located at 303 South First Ave., East Duluth.

L. D. Wallner

L. D. Wallner, general manager of the new company, has by training become well-fitted to serve the area both from an engineering and a sales standpoint. He is an alumnus of Stout Institute, graduate

SHAWINIGAN PRODUCTS CORPORATION
EMPIRE STATE BUILDING, NEW YORK 1, N.Y.

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The Trade-Name is "ANTI-BORAX"

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A Flux for every metal: Cast Iron Welding Flux No. 1; Brazing Flux No. 2; Braz-Cast Flux No. 4 for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; No. 16 Silver Solder Paste Flux.

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Fort Wayne, Indiana

For more than 30 years, K-G Welding and Cutting Company has manufactured welding and cutting torches and regulators with a single purpose in mind—to produce only the finest possible oxy-acetylene apparatus. That this aim has been achieved is demonstrated by the fact that with few distributors and little sales effort, K-G apparatus is in use far and wide. K-G torches and regulators have literally sold themselves . . . have proved so efficient and economical that many users have ordered and re-ordered *by mail* for many years.

Now, as a subsidiary of Air Products, Incorporated, K-G is putting into operation an entirely new and broader sales policy designed to make the K-G line available everywhere for direct purchase. New items are being added to provide a complete line of superior equipment for every welding and cutting requirement. Soon there will be authorized K-G distributors, with complete stocks and factory-trained repair experts, in all principal cities. In the meantime, users of apparatus are invited to learn more about the superior K-G line. Write today for the K-G Catalog—address K-G Welding and Cutting Company, Dept. 120, 515-19 W. 29th Street, New York 1, N.Y.

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TO USERS OF OXYGEN: Air Products, Incorporated, manufacture equipment for the economical production of oxygen, nitrogen and hydrogen by the user of more than 200,000 cubic feet per month. Learn how you can cut costs and speed production by producing your own gases with Air Products equipment—write for details. Address Air Products, Incorporated, Dept. B, Box 538, Allentown, Pa.

ing in 1936 with a degree in Metallurgy and Metal Working. He acquired additional technical credits by attending General Motors Tech in Flint, Mich.

From 1936 to 1940, Mr. Wallner was a welding instructor in Janesville, Wis., and Duluth, Min., and from 1940 to 1945 he was outfitting superintendent for the Zenith Shipbuilding Co. in Duluth. During the past year, from 1945 through 1946, he was employed as a welding engineer by The Lincoln Electric Co. in the Duluth area. Mr. Wallner is a member of the AMERICAN WELDING SOCIETY.

PRYOR ELECTED PRESIDENT OF MAGNOLIA AIRCO GAS PRODUCTS CO.

J. F. Pryor of Houston, Tex., has been elected president of Magnolia Airco Gas Products Co. according to a recent announcement. W. A. Sherman and R. F. Crow, former president and executive vice-president, respectively, who have been closely associated with the company for many years, will continue this active association as directors.

Also appointed vice-presidents were R. A. Merritt, former general manager of sales at Houston, and J. D. Schwartz, former branch manager of El Paso.

The Magnolia Airco Gas Products Co., which manufactures oxygen, acetylene and other industrial gases and also markets apparatus for their use, has plants and offices in Houston, Beaumont, San Antonio, Fort Worth, Dallas, Wichita Falls, Corpus Christi and El Paso.

P. M. HALL ACCEPTS APPOINTMENT AS TECHNICAL EXECUTIVE OF RESISTANCE WELDER MANUFACTURERS' ASSOCIATION

Preston M. Hall, one of the most outstanding figures in the Resistance Welding Industry, has accepted the position of Technical Executive of the Resistance Welder Manufacturers' Association.

P. M. Hall

A former president of that organization (1942), Mr. Hall has long been actively interested in Association work and in the advancement of the industry generally, serving as chief of the Resistance Welding Section, WPB, from 1942–45. During the summer of 1945, the Government sent Mr. Hall to England, Sweden and Germany as a special scientific consultant on welding, to investigate developments in those countries.

He also served the country in a distinguished manner as an explosive chemist during World War I, shortly after his graduation from the University of Maine in 1915, with a B.S. in Chemical Engineering.

He then became an experimental engineer for the Thomson Electric Welder Co. In 1923 he founded the Taylor-Hall Welding Co. and served as its president until the beginning of this year, when he resigned to devote his time and attention to being a special emissary of R.W.M.A.

Mr. Hall has made an outstanding contribution to the development and advancement of resistance welding by his invention of numerous machines and processes of great importance.

For the past six years, R.W.M.A. has been extremely active in the development of standards and specifications for resistance welding machines and equipment and has undertaken considerable educational, promotional and research work. Under the able direction of Mr. Hall, the Association is now greatly expanding this program.

Mr. Hall, whose headquarters will be the Association's office (505 Arch St., Philadelphia 6, Pa.), expects to spend considerable time in the field, cooperating with technical schools, engineering departments of universities, technical societies and with industrial users.

In addition, Mr. Hall will be available for consultation on the production problems of metal fabricators. His wide experience and splendid knowledge of all phases of resistance welding make him unusually well fitted for this new position, which will enable the manufacturers of resistance welding machines and equipment to be more closely attuned to the wants and interests of the industrial, technical and educational circles interested in the process.

RESISTANCE WELDER MANUFACTURERS ASSOCIATION ANNOUNCES NEW OFFICERS

George N. Sieger, president of S-M-S Corp., Detroit, Mich., was elected president of the Resistance Welder Manufacturers Association at their Annual Meeting at the Book Cadillac Hotel, Detroit, on January 17th.

For the past two years, Mr. Seiger has been most active in the expansive publicity and promotional work in which R.W.M.A. has engaged, serving as the chairman of the Association's most important committee—Publicity and Public Relations.

George N. Sieger

Under his able direction, the Association's *Resistance Welding Manual* has been extensively revised and enlarged and his committee has engaged in considerable educational and promotional work to bring to public attention the great strides made by Resistance Welding during and since the war.

A prominent figure in the welding industry, Mr. Sieger has, for a number of years, been active on committees of the AMERICAN WELDING SOCIETY and now serves as second vice-president of that organization.

His election to the presidency of the Resistance Welder Manufacturers' Association is in recognition of his outstanding cooperation, accomplishments and interest in the Association's activities, for this position has heretofore been held only by Resistance Welding Machine Manufacturers.

T. S. Long

T. S. Long, vice-president and general manager of the Taylor-Winfield Corp., Warren, Ohio, was elected to serve as the Association's vice-president.

Weltronic Announcing

A NEW SERIES

Non-Synchronous

WELD TIMER-CONTACTORS

New electronic circuits reduce moving parts to one NEMA 00 type relay for energizing solenoid valve on welder.

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FIRING RELAY ELIMINATED

Thyratron tubes fire ignitrons direct

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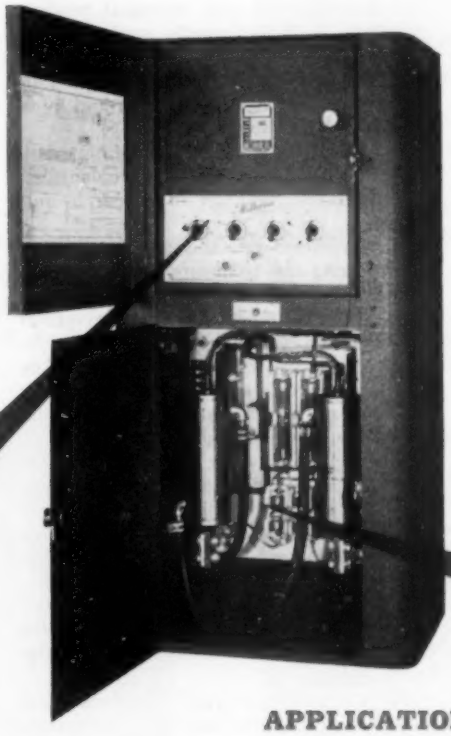
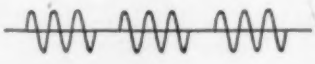
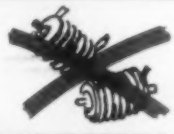




The start of every new weld is opposite in polarity to the finish of the last weld, thus preventing transformers from "building up" and saturating.



NO RECTIFIERS REQUIRED

Direct thyratron tube firing of ignitron contactor eliminates necessity of rectifiers. Same as on previous synchronous controls

MORE ACCURACY

Due to inherent characteristics of tube sequencing and tube ignitron firing far greater timing accuracy is obtained.

MORE WELDS PER MINUTE

Because sequencing and ignitron firing is fully electronic much of the mechanical element tending to slow up the welding cycle is eliminated. Timers can operate up to 500 welds per minute.

APPLICATION

Weltronic timer-contactors provide simple, low-cost means of accurate automatic electronic control of electrode movement and pressure, as well as duration of weld current. Use of timer-contactor relieves the operator of the timing and operating and virtually eliminates all burned welds. Models are available for foot operated spot, projection, and butt welders, including cam-timed machines.

These controls are complete "package" combination units, completely wired and ready to install. A universal wall or floor mounting cabinet houses either a NEMA 1A, 3B, or 5B timer and Ignitron Contactor.

WELTRONIC COMPANY

19500 West Eight Mile Road — Detroit 19, Michigan

Mr. Long has been extremely active in the work of the Association for several years, serving during 1946 as chairman of the Arbitration Committee.

BIRINYI JOINS BATTELLE

Louis K. Birinyi, Welding engineer, has been appointed to the staff of Battelle Institute, Columbus, Ohio, where he will be engaged in research on welding materials and processes.

Mr. Birinyi is a graduate of Ohio State University and a member of the American Welding Society. Prior to entering the Navy in 1944, he was associated with the Cramp Shipbuilding Company, Philadelphia, Pa.

STEEL STACK

Largest of its kind in the U. S., this 250-ft. self-supporting butt-weld steel stack at the National Carbide plant in Louisville, Ky., was fabricated by the Ingalls Iron Works, Birmingham, Alabama. The stack, which is a dust collector, measures 22 ft. in the inside diameter at the base and 15 ft. at the top.

Steel Stack

Employment Service Bulletin

SERVICES AVAILABLE

A-540. Wide experience in the resistance welding field, in designing regular, and special, light and heavy duty machines of all descriptions. Wide experience in sales and special engineering. Would like to organize new company or represent a good company. Prefer to remain on the Pacific Coast. Salary open.

A-542. 14 years' experience in welding, last four years teaching basic welding to infantry mechanics. Two years as welding inspection foreman in large eastern aircraft factory. Have B.S. degree in engineering. Passed pipe line arc welding code in 1939. Would like a job as Welding Engineer, Welding Inspector or Welding Supervisor. Will work anywhere inside or outside U. S. Specialty spot welding nonferrous alloys.

PROGRESS OF WELDING IN GREAT BRITAIN

Progress of welding in British industry during recent years has practically coincided with the expansion of the Institute of Welding, which was founded in 1923. Its membership is now over 5000 and in addition to high executives in the welding world the membership, especially Associateship, includes many who are concerned with the more practical and operative side of welding. The principal functions of the Institute of Welding may be summarized thus:

(a) To stimulate cooperative research into fundamental and practical welding problems, and the speedy application of the results in industry, by the maintenance of close and continuous relations between industrial development and laboratory investigations.

(b) To provide a central pool of organized information, constantly replenished by the latest findings of research and practice.

(c) To formulate standards of education and training and to ensure that an appropriate knowledge of welding shall form part of the technical equipment required for all branches of engineering.

(d) To ensure that any regulations or standards set up for the control of welding shall rest on sure foundations of scientific knowledge and practical experience.

Research has always been prominent in the Institute's activities and its Welding Research Council has now evolved into a separate organization known as the British Welding Research Association, which is one of the most vigorous scientific organizations in the United Kingdom. Although the Research Association is a separate body there remains a close association with the Institute.

For the propagation of knowledge and information on welding the Institute's Publications Department has long been a factor of importance. Its main publication is the *Transactions*, which is published every two months and as soon as the paper position becomes easier it is hoped to publish the *Transactions* monthly. The Institute's *Handbook for Welded Structural Steelwork* is a standard reference book on the subject. More than 3000 copies were sold before publication and the book has frequently been reprinted. In addition, a thoroughly revised edition has recently been issued.

Another popular contribution the Institute makes to welding science and industry is its Library and Information Service, the Library containing the most complete collection of printed information on welding available in Great Britain.

The Institute's Headquarters are in London and throughout the country are some twenty branches, which thus make the Institute representative of welding progress throughout Great Britain.

TEMPLETON, KENLY & CO. BULLETIN

Templeton, Kenly & Co., Cicero, Ill., manufacturers of Simplex Jacks for use by mines, railroads, industrial engineering and construction, has recently issued a new descriptive bulletin on its Simplex Util-A-Tool. Designed to facilitate welding and many other industrial plant applications by means of clamping, this No. 610 set as outlined in the bulletin provides multipurpose equipment that also pushes, spreads, pulls and lifts easily and efficiently.

The center spread of the bulletin describes in detail the various industrial plant uses of the Util-A-Tool, one of which is welding. The tool clamps and holds parts for welding or assembly on the corrugated clamping lugs, straightens structural and pressed steel members and holds down portable machines.

Listed on the bulletin's back page is a wide selection of push-and-pull jacks and steamboat ratchet pulling jacks. Specification charts and price listings on these and the Util-A-Tool are included. For full information on any of the Simplex jacks write for Bulletin P & P 46, Templeton, Kenly & Co., 1020 S. Central Ave., Chicago 44, Ill.

BOOK CATALOGUE

Chemical Publishing Co., Inc., 26 Court Street, Brooklyn 2, N. Y. has just issued their new 1947 catalog. The catalog includes the latest books on chemistry, technology, physics, general science, mathematics, engineering, foods, formularies, drugs and cosmetics, medicine, metals, technical dictionaries, etc., as well as college and other textbooks.

Librarians, technical and scientific workers will find this catalog especially useful as it conforms with many of their specific needs in listing the data of publication of each book, as well as price, number of pages, descriptions and full table of contents.

Keep up with the latest developments in science and industy by writing direct to the publisher for a *free* copy of this catalog.

New Giant Bases Built from Welded Plate

BY A. E. LOFTQUIST, MGR. OF FABRICATED PLATE DIV.
R. C. MAHON COMPANY, DETROIT, MICHIGAN

Press beds and die bases weighing 23 tons to 25 tons each, formerly built from structural members, are now being fabricated from plate for lower costs, greater strength and permanent rigidity. The former design, involving channels, I-beams and angles, had stresses concentrated at the joints; it was ungainly and costly, requiring expensive layout and assembly. Redesign for plate construction has made stress distribution uniform, has given our customer a better product, with more attractive appearance.

The 25-ton press bed shown in Fig. 1 is one of 16 of this modern design, welded from ¾″ and 1″ plate. This pedestal, 11 ft.-4¼ in. wide, 19 ft.-6 in. long and 14 ft.-10 in. high, will be installed in a pit, its top flush with the shop floor and will support a giant press.

The base shown in the foreground of Fig. 2 is a 23-ton die bed, built from plate as heavy as 3″ thick and from formed sections.

Special procedures were not necessary to control warpage and distortion because proper design kept this to a minimum. Reasonable care was used to properly balance welding from side to side.

New Electrode Simplifies All-Position Welding

The large size of these weldments makes it impractical to use positioners in order to get all downhand welding, but the bases are turned over from one side to another and end to end, to eliminate vertical and overhead welding in almost all cases.

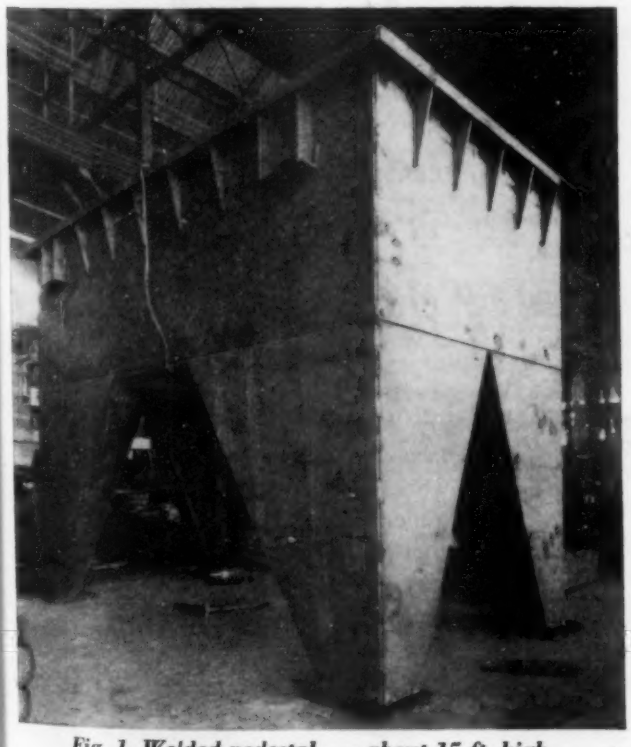


Fig. 1. Welded pedestal . . . about 15 ft. high.

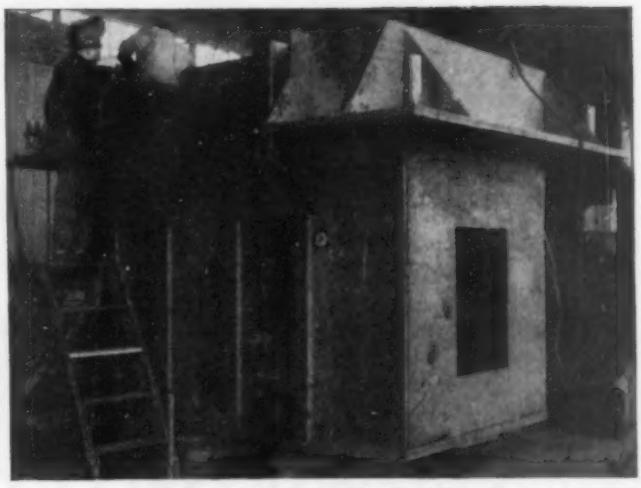


Fig. 2. Die bed . . . weight 23 tons.

In this welding, involving fillets, corner joints and bevelled butt joints in heavy plate, we have used the new Lincoln "Fleetweld 47" extensively so as not to sacrifice time or quality. It is also used for the welding of fillets in the lighter plate of various attachments and stiffeners.

In making horizontal fillets, we lightly drag the coating of the electrode on the flat plate, maintaining a space of 1/16″ to ⅛″ between the electrode and the vertical plate. This makes the weld "feather" into the vertical plate.

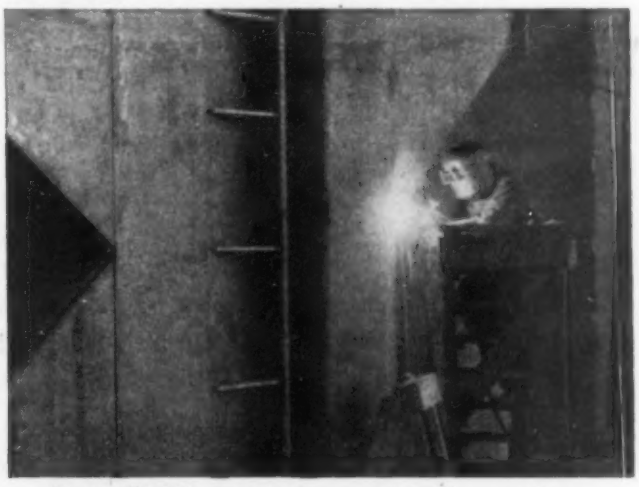
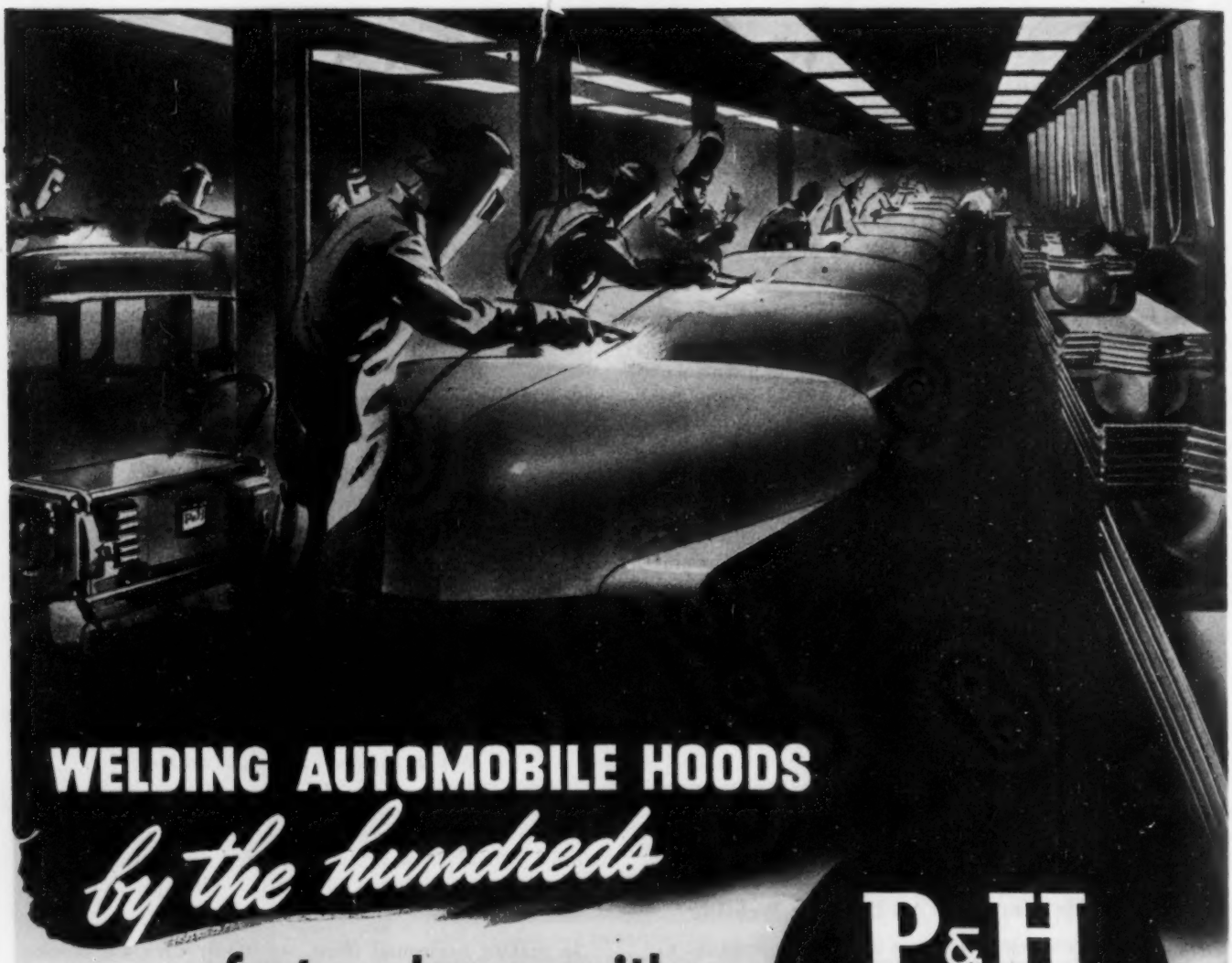


Fig. 3. Welding vertical corner joint in press base.

We use this E-6013 electrode in sizes as large as ¼″ for vertical welds, resulting in speeds up to 40% faster than with small size electrodes. Welds are made vertically upward with single pass weave.

Further information on the procedure for this electrode may be obtained by writing The Lincoln Electric Company, Dept. 123, Cleveland 1, Ohio.

Advertisement



WELDING AUTOMOBILE HOODS *by the hundreds*

faster, cleaner with . . .

P&H

"SM"

FOR SHEET METAL WELDING

(CLASS AWS-ASTM-E6013)

It's sheer performance—not casual selection — that makes "SM" first choice for welding automobile hoods. Comparative tests, made by a leading builder of quality cars, again showed "SM" first in speed, quality and appearance.

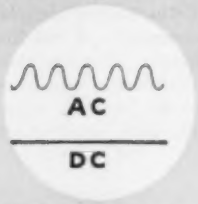
On jobs like this, welds have to *look* right as well as *be* right. Hoods are formed from two halves welded along the *top*. The slight crown of the bead minimizes finish grinding and eliminates additional surface preparation.

"SM" provides every desired operating characteristic. It's fast — "SM" is a true production electrode. "SM" eliminates the hazard of "burn-throughs" and "suck-ins." Slag removal is easier.

"SM"

TRIAL OFFER

Try this remarkable electrode in your own shop, on your own work — without cost or obligation. Simply write for a free trial package of "SM." You, too, will agree that "SM" is America's outstanding electrode for sheet metal welding.



AC OR DC — Yes, whatever your machines, AC or DC, whatever your work, "SM" performs perfectly. It's the true production electrode for welding thin gauge metals.

LOWER PENETRATION — You get less penetration—the *desired* amount of penetration with "SM." Gone are your troubles of "burn-throughs" and "suck-ins." Use "SM" on metals down to 20 gauge.

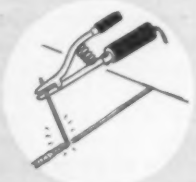
"DROP OFF" SLAG — A really unusual and important feature of "SM" — main reason why one of America's largest light gauge fabricators uses it exclusively. Slag removal is no problem with its "drop off" characteristic.

"SM" gives you—

ALL-POSITION — Whatever you're fabricating — auto or truck bodies, tanks, furniture, window frames, etc., you can weld them in any position. All-position welding rounds out "SM's" versatility — makes it an electrode you can't afford *not* to use.

CONVINCE YOURSELF—TRY "SM"

SPRAY TYPE ARC—Specially developed coating gives "SM" *ideal* concentrated spraying action for faster, smoother, stronger welds on all positions.

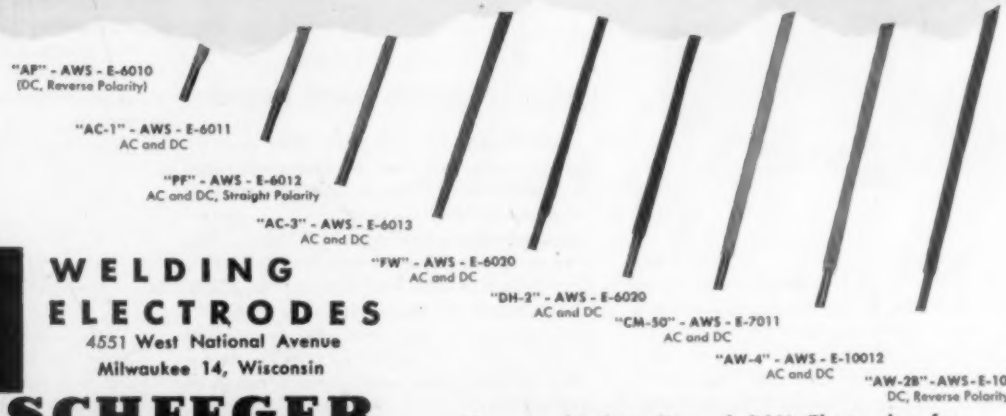


REDUCED SPATTER LOSS—The extremely small amount of spatter greatly increases welding efficiencies of "SM."

FLAT, THIN BEAD — Another important advantage: Its very smooth, flat bead. Say goodbye to "humped" or convex bead that requires expensive grinding, careful finishing.

OTHER POPULAR P&H MILD STEEL ELECTRODES

There's a production approved electrode for every requirement in the complete P&H line. Below are just a few. Get complete information from your P&H representative or write us.


"AP" - AWS - E-6010
(DC, Reverse Polarity)
"AC-1" - AWS - E-6011
AC and DC
"PF" - AWS - E-6012
AC and DC, Straight Polarity
"AC-3" - AWS - E-6013
AC and DC
"FW" - AWS - E-6020
AC and DC
"DH-2" - AWS - E-6020
AC and DC
"CM-50" - AWS - E-7011
AC and DC
"AW-4" - AWS - E-10012
AC and DC
"AW-2B" - AWS - E-10020
DC, Reverse Polarity

P&H

HARNISCHFEGER CORPORATION

WELDING ELECTRODES • MOTORS • HOISTS • ELECTRIC CRANES • ARC WELDERS • EXCAVATORS

WELDING ELECTRODES

4551 West National Avenue
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Also a complete line of P&H Electrodes for stainless and alloy steels, as well as for hard surfacing.

AMERICA'S MOST COMPLETE ARC WELDING SERVICE.

DC Welders | AC Welders | Welding Electrodes | Welding Positioners | Welding Production Control Systems | Electric Hoists | Electric Cranes

NEW PRODUCTS

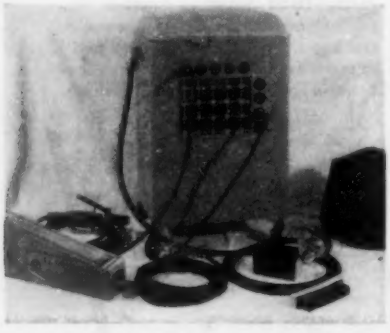
The Society assumes no responsibility for the validity of claims in this Section

HIGH-SPEED STEEL WELDING RODS

The Welding Equipment & Supply Co., of 223 Leib St., Detroit 7, Mich., announces the new literature covering their Eureka No. 2 High-Speed Steel Welding Rods. This six-page folder is graphically illustrated and gives physical properties, heat-treatment and uses of the product. Welding procedures are outlined in using these rods for repairing high-speed steel cutting tools; for compositely fabricating cutting tools, for creating cutting, wearing and bearing surfaces.

LIMITED-INPUT TYPE WELDER

A general-purpose transformer arc welder, designed for use on single-phase power lines of limited capacity, is available from Westinghouse Electric Corp. in three output ratings: 130, 160 and 180 amp. The welder comes complete with line breaker, power cable with plug and receptacle, insulated electrode holder, electrode lead with holder and adjustment plug, work lead with ground clamp and adjustment plug, electrodes, helmet complete with lens and cover glass, wire brush and a welding instruction manual.



The three models, WT-13, WT-16 and WT-18, bring to the farmer or owner of a small repair shop a welder ideally suited to the repair jobs they have to do. They have 20 steps of foolproof current adjustment between 20 amp. and the rated maximum. They provide two striking voltages: 65 volts for small electrodes on the lower half of the range; 50 volts for larger electrodes on the upper half of the range. There are Deion circuit breakers to control the flow of current to the welder and to give overload and short-circuit protection. Class B insulation, the best grade available, is used throughout. Design provides adequate natural ventilation. No moving parts,which means a minimum of maintenance.

These welders are designed to conform to the standards of the National Electrical Manufacturers' Association, to meet the requirements of the R.E.A. and are listed by the Underwriters Laboratories, Inc.

Further information on these welders may be secured from Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30, Pa.

ALUMINUM BRAZING ROD

All-State Welding Alloys Co., Inc., 96 West Post Road, White Plains N. Y., announces the immediate availability in unlimited quantities of a new brazing rod for sheet aluminum. This rod has astounded those who have had opportunity to use it and many others who have seen it in use. It makes beautiful smooth, clean joints and is particularly good for use on very thin sections of aluminum. It melts at a temperature well below the melting point of sheet aluminum and less preheat and less flux is required than for rods that have been previously available. The new brazing rod can be used without danger of burning through even the thinnest sheet aluminum used commercially.

This rod has been especially developed for repairing aluminum coach bodies, manufacturing furniture and cooking utensils and for many other applications where its low melting temperature and economy in use are essential factors. It produces corrosion-resistant welds with good matching color and a tensile strength of 30,000 psi. This new product is known as All-State No. 31 sheet aluminum brazing rod.

MOTOR-OPERATED FLASH WELDERS

A technical bulletin (No. 204) describing its improved line of motor-operated flash welders—which are said to represent the most modern development in motor-operated, flash-welding equipment—has been made available by Progressive Welder Co., 3050 E. Outer Dr., Detroit 12, Mich. Construction of these machines combines both universal and specially engineered features and is designed to provide versatility of operation over a wide range of applications.

Convenience of operation and setup and outstanding performance characteristics are said to be features of these flash-welding machines second in importance only to their versatility. Entire machine control is from one position; and all settings such as those for flashing voltage, amount of upset, platen travel speed, etc., can be made within a few minutes.

The bulletin lists four basic sizes having ratings at 50% duty cycle of 20, 50, 100 and 150 kva. and upset forces of 2250 lb., 4500 lb., 11,500 lb. and 19,600 lb., respectively. The machines are also available as storage battery operated units.

The bulletin carries complete specifications, photographs of machines and detailed closeups. There is also a phantom cut-away sketch of a typical machine with labeled arrows locating operational features and the main working parts.

GOGGLE CLEANING

A new safety goggle cleaning station which can be attached to the wall at strategic locations throughout plants is announced by American Optical Co., Southbridge, Mass. As a constant reminder for workers to keep their goggles clean, the new lens cleaning cabinet reduces the possibility of accidents or spoiled work cause by blurred vision.

Made from selected hardwood, in safety green color, with smoothly lacquered finish, the cleaning station is designed in a small, compact unit, with provisions for all necessary cleansing and antifog materials. It is 13 in. long, 9 in. high and 6 in. deep.

Directions for using the goggle cleaning station are printed on the front panel of the cabinet. Supplies of the necessary lens cleaning fluid, cleansing tissues and antifog compound for reducing fogging, steaming and frosting of lens surfaces are also obtainable from the optical company.

PHOTOSWITCH ELECTRONIC WELDING TIMER

Photoswitch Electronic Welding Timer Type 30CR3 is designed for interval timing of welding operations over a range of 3 to 120 cycles. It is recommended for all general-purpose spot welders and fulfills the specifications of N.E.M.A. Class 1A Timers. It is applicable to manual-, air- or motor-operated welding equipment requiring either beat or nonbeat operation.

The timer incorporates many features of particular importance to the welding field. The timing adjustment can be set for any interval from 3 to 120 cycles. It is calibrated at these two settings, and its accuracy throughout the range is within 2%. The timing adjustment is located on the panel inside the housing, thus pro-

FOR SHIELDED ARC AUTOMATIC WELDING

RACO COMPOSITE TYPE "A"

THE NEW AND REVOLUTIONARY ELECTRODE FOR AUTOMATIC ARC WELDING

RACO Composite Type A is a heavily coated electrode in coils, providing the same physical results as heavily coated manual electrodes. With RACO Composite Type A, extremely high speeds can be obtained in any position.

It can be used with all standard automatic arc welding heads without alterations or additions.

RACO Composite Type A can be had with any of the following coatings—A.W.S. 6012; 6020; 6030 and corresponding high tensile grades. This electrode can also be furnished in three grades of hard surfacing material for building-up—RACO 25 (20-25 Rockwell C), RACO 45 (40-50 Rockwell C) and RACO 55 (50-60 Rockwell C). RACO Composite Type A Electrode is furnished in the following sizes: No. 6 (approx. 1/4"), No. 5 (approx. 7/32"), No. 4 (approx. 3/16"), and No. 3 (approx. 5/32"). Coils are 36 inches I.D., and weigh 150 to 200 pounds net.

LIGHTLY COATED AUTOMATIC ELECTRODES:—

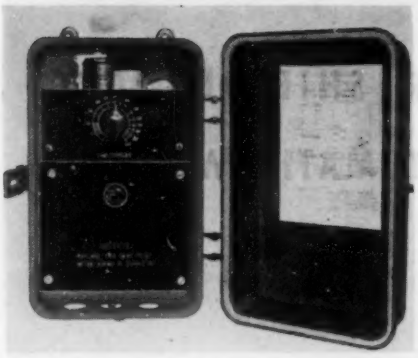
RACO Types "D", "M", M-9 (Knurled), Plain Mill Finish and Copper Coated Wire in coils.

We draw a full line of copper coated oxy-acetylene welding wires. Furnished in coils and straightened and cut lengths.

We further manufacture a complete line of heavy coated manual electrodes for welding:—Mild Steel—High Tensile Steels—Stainless Steel—Manganese Steel—Cast Iron—Nickel—Monel—Inconel and Aluminized Steel.

The REID-AVERY COMPANY
INCORPORATED
DUNDALK • BALTIMORE 22 • MARYLAND

SINCE 1919 PRODUCERS OF ARC WELDING ELECTRODES AND WELDING RODS



viding a tamper-proof setting. The timer may be used with either a 115 or 230 v. a.-c. supply. By simple selection of terminals on the terminal panel, the timer will provide beat or nonbeat timing (initiation of timing cycle from momentary contact or sustained contact). The terminal panel is provided with a dead front so that there is no possibility of the operator touching the terminals when setting the timing interval.

Combinations of Timer Type 30CR3 are used when it is desired to control also other portions of the welding cycle, such as the squeeze, heat, cool, on and off periods.

WELDIT WELDING TORCH

Torch W-46 now embodies an outstanding new feature that permits of wider operating range and easier handling—the full "handle length" lever makes it possible to shut off or release gas with only fingertip pressure. This new feature combined with the built-in Automatic Gasaver makes W-46 the outstanding welding torch of the day. Carefully checked tests under ordinary working conditions show that W-46 has effected a gas saving of

$4.80 per man per day. Production in many plants showed an increase of 100% and in a few ranged as high as 148%. Tests with ordinary production torches also prove that only 20 sec. of flame is actually used in welding—a two-third-gas waste that can be saved with the W-46. Descriptive literature will be mailed upon request. Weldit, Inc., Dept. 100, 990 Oakman Blvd., Detroit 6, Mich.

NEW ULTRASONIC MATERIALS TESTER

A new ultrasonic materials tester designed to indicate the presence of voids, cracks, porosity, laminations, poor bonds, and other internal flaws in metals, plastics, and ceramics has been introduced by the Special Products Division of the General Electric Co. The tester is useful in production testing of metal castings, forgings, or finished machine parts, as well as plastic or ceramic parts.

The new tester sends a beam of ultrasonic waves through the specimen being tested. Changes in the amount of energy transmitted through the specimen are an indication of the presence and extent of flaws. The tester is portable and self-contained, easy to use, and provides a direct reading. Testing is not affected by small changes in dimensions or position of test pieces.

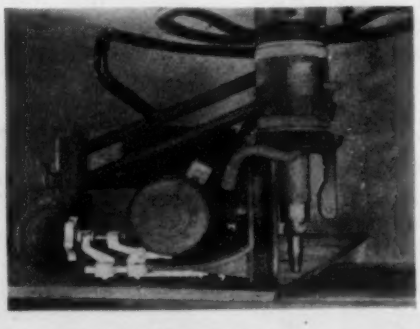
The new instrument consists of a complete wide-band ultrasonic transmitting-receiving system having a high-frequency generator, a crystal transducer for producing ultrasonic vibrations, a satisfactory medium such as water to transmit these vibrations, a second crystal transducer to convert the received mechanical energy into electrical signals, and an indicator supplying information for materials inspection or analysis.

To examine regularly shaped specimens, the two transducers are immersed in a tank containing water, and the specimen is inserted between them. Ultrasonic waves are then sent through the specimen, and the resulting reading on the indicating instrument is compared with that for a specimen shown to be sound by X-ray, mechanical breakage or sectioning methods. Internal flaws will produce measurable decreases in total transmission of waves through the specimen, and a consequent drop in the instrument reading.

The instrument can also be used to indicate changes of viscosity, compressibility, and density of liquids, when these significantly alter the velocity or attenuation of ultrasonic transmission.

A NEW ATTACHMENT SAVES SCRAP IN OXYACETYLENE CUTTING

A new attachment which makes oxyacetylene circle-cutting possible to the extreme edge of a plate, and in the corner of any plate, has been developed by The Linde Air Products Co., Unit of Union Carbide and Carbon Corp. This accessory for the OXWELD CM-16 portable shape-cutting machine is known as the Under-the-Motor Circle-Cutting Attachment. The main advantage of the attachment is that metal can be utilized that would ordinarily have to be scrapped.

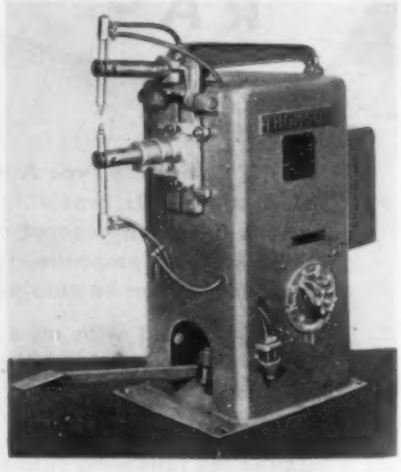


The CM-16 Cutting Machine with the Circle-Cutting Attachment Mounted in Place

The attachment makes it possible for the standard CM-16 cutting machine to cut circles from 2½ to 9 in. in radius. The radius of the circle to be cut is regulated by means of an adjusting screw. Circles above 9 in. in radius can be cut to the extreme edge of a plate without the attachment. The attachment is easy to install and once in place, normal cutting procedures are followed.

ROCKER ARM SPOT WELDERS

A new series of rocker arm spot welders, designed to handle work in the light medium range, is offered by the Thomson Electric Welder Co. of Lynn, Mass. Available either as foot-, air- or motor-operated machines with 12, 24 or 30 in. throat depth and 20, 30 or 40 kva. transformer capacity, this series provides a choice wide enough to include "all purpose" machines for shops doing general spot welding and special duty welders for mass production assembly line work.



In addition to the rocker arm action which is generally preferred for this class of resistance welders, Thomson "R" Series Spot Welders have many features designed to improve performance and simplify maintenance. These include: patented Thomson tubular secondary transformer with noncorroding, nonclogging secondary sections and hard-rolled primary windings; fabricated steel frame substantially reinforced to minimize deflections; heavy duty, 8-point positive clamp type heat regulator with star locking wheel to prevent drifting and insure efficient contact; indexed terminal block on which all wiring of air or motor operated machines is centralized to facilitate maintenance, testing and inspection. Electrodes and transformers of all models in this series are water cooled from separate circuits with individual flow control and visual water drain.

HOW WOULD YOU HARD-FACE *These Parts* ?

That's the $64.00 QUESTION

—and the COLMONOY SPRAYWELDER is the million dollar answer

The parts shown above have to be extremely resistant to both corrosion and abrasion. In addition, they have a rather intricate design which presents quite a hard-facing problem, inasmuch as they must be finished to ± .001" on all dimensions.

Conventional hard-facing methods, of course, could not be considered.

With the COLMONOY Sprayweld Process, however, this is just another routine job. The parts were first grit-blasted, after which an overlay of Colmonoy No. 6 was sprayed on and then fused to the base metal. Distortion and warpage, .001.

Amazing? No more so than the fact that the Colmonoy Spraywelder is so low in price that any shop can have one. And the process is so easily executed that anyone can do it.

WRITE

for Complete Information

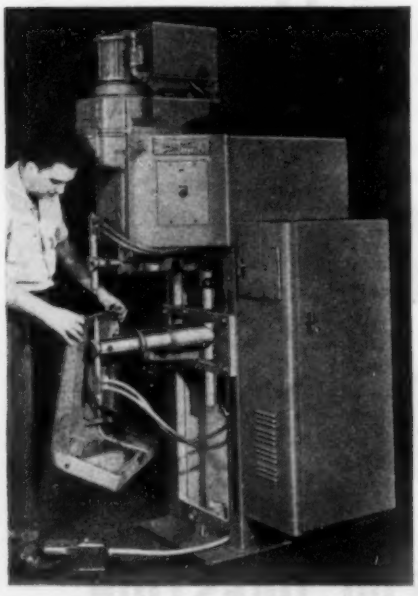
The Colmonoy Spraywelder, combining metallizing and welding, opens up new opportunities for profitable operations. Write for new literature and full information.

WALL COLMONOY CORPORATION

7TH FLOOR FISHER BLDG., DETROIT 2, MICH.

PRESS WELDERS

The new Type ENB press welders are designed to meet present-day requirements for rugged but precise spot and projection welding service with long life and low maintenance. A number of new and outstanding features are incorporated in this design including the roller antifriction welding head, tap switches connected to the transformer without flexing primary leads, provision for use of side mounted electrical controls, composite copper-steel knee construction insuring maximum rigidity when projection welding, transformer design of "damge-resisting" construction and air valves mounted adjacent to air cylinders resulting in low air consumption and high operating speeds. These welders are engineered with additional optional features, such as bellows air lock mechanism with low voltage firing switch, adjustable stroke cylinder, adjustable-retractable stroke cylinder with either hand valve or solenoid valve and foot-switch operation, series-parallel tap switch and various types of horns, electrode holders and dies for spot and projection welding.



Type ENB, Style 4, Spot Welder, Air Operated, 18 In. Actual Throat Depth with Side Mounted Electrical Controls

MILLIONTH-OF-SECOND COUNTER DEVELOPED FOR X-RAY MEASUREMENT

Development of an electronic X-ray counter that accurately records X-rays at millionth-of-a-second speed over a wide range of intensities has been announced by Dr. Fitz-Hugh Marshall and Dr. John W. Coltman, Westinghouse research engineers.

First all-purpose tool for the measurement of X-radiation, this X-ray detector in high-speed tests has approached the ultimate in sensitivity by providing exact measurement of the smallest X-ray units known as well as intense radiation.

Fig. 1

A white fluorescent "vest" and black paper "coat" are necessary items of attire for the super-sensitive photomultiplier tube that plays the key role in the new X-ray meter. Dr. Fitz-Hugh Marshall, Westinghouse research engineer, is shown placing the black paper over the white fluorescent screen which surrounds the tube. When the device is in operation to measure X-rays, the rays are beamed directly at the tube. The black paper blocks out all room light but allows the X-rays to penetrate to the fluorescent screen, causing it to fluoresce. This fluorescence sets up a tiny electric current in the tube which then is amplified one million times to make possible exact measurement of changes in radiation intensity.

The difficulty of measuring X-rays always has been a scientific headache, according to Dr. Marshall. The Geiger counter of the type used at the Bikini atom bomb tests to warn of radioactivity measures only low intensities of radiation. Development of such a highly sensitive and versatile instrument as this new counter, therefore, gives science a valuable tool for fundamental research as well as pointing the way to possible future industrial applications of X-ray equipment.

NEW LIGHTWEIGHT PALLET LIFT TRUCK

Completely new design, construction and operational features are offered by Lyon-Raymond Corp., 3260 Madison St., Greene, N. Y., in their new 2000-lb. capacity hand pallet truck.

Total enclosure of working parts serves to protect them as well as give a streamlined appearance to the truck. The use of high strength alloy sheet steel formed into box sections for the frame, and aluminum alloy for wheels and other nonstructural parts insures a minimum of weight. Two men can load this truck from ground level into a highway truck.

Elevation is accomplished through a hydraulic foot pump, especially designed for the truck. Length of stroke is optional, depending on the stature of the operator. Lowering results from pushing the foot pedal forward. The pump is equipped with a relief valve to prevent overloading and possible damage.

Full details and price information are available from the manufacturer. Simply write for copy of Bulletin No. 221.

FLASH WELDERS

An improved line of standard motor-driven flash welders, representing the most modern development in motor-upset flash welding equipment, has been announced by Progressive Welder Co., 3050 E. Outer Dr., Detroit 12, Mich. These machines have been designed for precision flash welding virtually any metal, including aluminum, for long periods at high production.

They combine both "universal" and "specially engineered" features, making possible a wide range of applications without major alterations in the basic machines. Machines may be operated either a. c. through transformers, or d. c. through the use of storage batteries. All units—including all electrical and mechanical units—are enclosed within the machine frame for greater cleanliness and reduced maintenance. Flat tops on most of the machine types also help make these welders more universal in their applications.

Convenience of setup and operation is an outstanding feature. Entire machine control is from only one position. Platen travel speed for flashing and upset; flashing voltage; amount of upset; die openings, and other necessary settings can be made within a few minutes. Once made, they are accurately maintained to assure duplication of weld performance.

Welding speeds in these improved ma-

What... Remodel Iron Parts Already Cast?

Yes, right on the production line ...with NI-ROD

BEFORE: Here's the original cast iron manifold and the extra port. After inspection of both parts, the manifold was preheated to 450°F.

Here's an interesting Ni-Rod case history ...*

It shows how easily Ni-Rod can simplify design changes and speed production.

Grey iron manifolds like the one at the top became outmoded when an additional port was required.

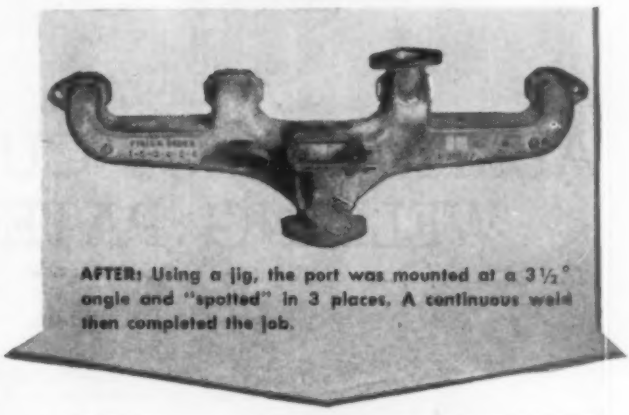
But, quickly and easily, Candler-Hill Corporation, of Detroit, remodeled the manifolds on hand, using Ni-Rod.

Saving time, money and labor ... this company cut a correctly located hole in each casting, then welded on a secondary port using an a.c. transformer-type welder drawing 160 amperes.

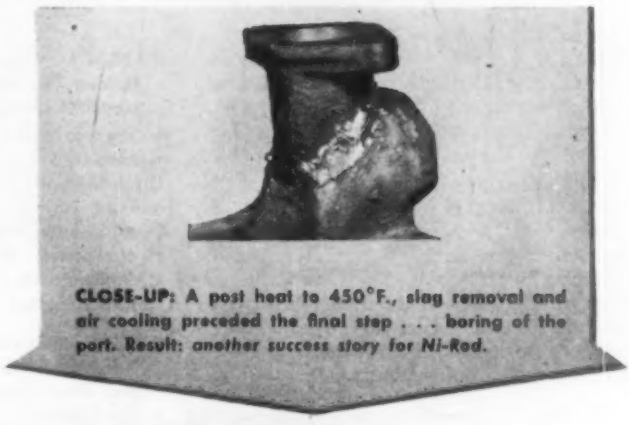
Since other rods gave less favorable results, Candler-Hill was particularly gratified with Ni-Rod. It speeded-up the process, required less preheat and post heat, and the machinability of the weld allowed quick boring of the port. Position of ports was held within ± ½°, and all other dimensions were held within ± .003".

Try a 5-lb. package of Ni-Rod. Use it on a.c. or d.c., and see how easy it is to get strong, sound, machinable welds in cast iron.

*Reg. U. S. Pat. Off.



AFTER: Using a jig, the port was mounted at a 3½° angle and "spotted" in 3 places. A continuous weld then completed the job.



CLOSE-UP: A post heat to 450°F., slag removal and air cooling preceded the final step ... boring of the port. Result: another success story for Ni-Rod.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

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PACIFIC METALS COMPANY, LTD.
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EAGLE METALS COMPANY
Portland, Seattle

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ALLOY METAL SALES, LTD.—Toronto

WILKINSON COMPANY, LTD.
Vancouver

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chines have been materially increased by close coupling of the welding current. This provides increased efficiency and also results in higher welding current for a given flashing voltage. Another feature is the side rail construction of the moving platen which consistently maintains accurate product alignment.

Other noteworthy improvements in this line of Progressive flash welders are the one piece rugged frame construction; multistep taps on the transformers permitting 16 distinct steps from 30 to 100% of capacity; greater safety to operator and operating units through protective streamlining; easier loading arrangements; and better cooling control.

The improved Progressive motor-driven flash welders are available in 4 capacities from 20 kva. to 150 kva., or they may be battery operated for any welding job that is within the physical capacity of the machine. Upset pressures are 2250 lb., 4500 lb., 11,500 lb. and 19,600 lb. for the four machine sizes; maximum stock width, vertical fixture, is 2, 4, 6 and 8 in.; and maximum tube O.D., vertical fixture, is 1, $1^1/_4$, $1^3/_4$ and $2^3/_4$ in.

Standard equipment furnished with all types of flash welders includes clamping fixture with one set of plain dies with hand or foot valve as desired; Cone-Drive speed reducer; upset mechanism with heat switch for energizing contactor for current on and off time. Such standard extras as air clutches; air pressure regulator and gage assemblies; and series parallel regulators are available.

ABSTRACTS OF CURRENT WELDING PATENTS

Prepared by V. L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington 10, D. C.

2,412,281—Torch Beveling Apparatus—Chester Mott, Evanston, and Glenn V. Wallace, Jr., Chicago, Ill., inventors, and assignors to National Cylinder Gas Co. (10 Claims)

This apparatus has a cutting torch, and a pilot member for riding on the surface of a workpiece being cut, which member supports the torch so that the torch is retained at a constant distance from the workpiece. The torch is adjustable with relation to the pilot member and has an adjustable support for use when the torch and pilot member are off of the workpiece.

2,413,189—Stud Welding Machine—Ted Nelson, inventor, San Leandro, Calif. (18 Claims)

The stud welder has a reciprocable stud holding plunger, primary means for moving the plunger in one direction and secondary means for moving the plunger in the opposite direction. Means for seizing the plunger when the primary means is actuated and means for releasing the plunger when moved by the secondary means are also provided.

2,413,213—Electrode Holder—William E. Cardinal, inventor, Cherry Lake, Fla. (1 Claim)

Cardinal's holder has an electrode receiving head section which is pivotally secured to the handle section. Insulator sleeves encompass the head and handle sections and the joint therebetween while an insulator collar, having a flared bore for guiding a weld rod into its socket, is positioned in the head section.

2,413,370—Welding Stud—Walter E. Palmer, inventor, Fair Lawn, N. J., assignor to Hollup Corp. (4 Claims).

The patented stud is adapted to be welded to a metal plate and the stud has a threaded body portion. The body portion has an end of reduced diameter which terminates in a point that is to be secured to the plate. A layer of fluxing material is deposited on the reduced diameter section of the stud.

2,413,663—Flash Welding Machine—Julius B. Tiedemann, inventor, Milwaukee, Wis., assignor to A. O. Smith Corp. (15 Claims)

This machine has a base that supports a pair of relatively movable electrode carrying frames one of which supports a transformer. The electrodes are supported for vertical movement with relation to their mounting frames, and they are adapted to apply clamping pressure to work positioned on movable work supports on the base of the machine.

2,413,783—Welding Control Apparatus—Hugo Purat, inventor, Detroit, Mich., assignor to Progressive Welder Co. (6 Claims)

Purat's welding machine has two opposed electrodes and individual means for moving each electrode to and from a work engaging position. A common power source is provided for the electrode moving means to move the electrodes to a work engaging position and to move one electrode with relation to the other. Other means actuate the electrode moving means to retract the electrodes from a work engaging position.

2,414,043—Variable Resistance Welding Electrode Holder—Jack C. Honhart, Detroit, and Earle W. Bagg, Harsens Island, Mich., inventors. (1 Claim)

This patent covers an adjustable rheostat that has a plurality of spaced convolutions of a resistance element and a cam shaped contactor member for engaging with the resistance convolutions by a rolling contact. A manually operable member is provided for actuating the contactor member.

2,414,345—Oxyacetylene Welding or Cutting Equipment—Henry Alfred Ernest Talley, inventor, London, England, assignor to Medical & Industrial Equipment Limited. (5 Claims)

The apparatus has a welding tube which has a jet and a tube surrounding the jet and having a restricted area adapted to cooperate with the jet to produce subatmospheric pressure. Oxygen and acetylene gases are supplied to the apparatus and a sensitive demand regulator is provided to control the flow of acetylene. The regulator has a diaphragm with atmospheric pressure on one side and with its other side connected through a control to the jet and tube so that the pressure thereat controls the regulator.

2,414,564—Portable Welding Fume Exhauster—Leslie Silverman, Westwood, and Frederick J. Viles, Jr., Boston, Mass., inventors. (10 Claims)

The portable fume exhauster has a housing with inlet and outlet ports and an exhaust fan for drawing gas through the exhaust port. A filter bag is provided in the housing and is controllable from outside the housing.

2,414,750—Oxyacetylene Cutting Machine—Fred B. Loucks, Jr., inventor, Milwaukee, Wis. (2 Claims)

Loucks' patent discloses a machine having a manually rotatable shaft which positions a bar thereon by a pair of travelers. A rod is positioned on the bar and mounts an instrument holder at its front end.

2,414,780—Electrical Welding Machine—Harold Uren, Chigwell, and Reginald Thomas Albert Dollisson, Ilford, England, inventors. (6 Claims)

This novel machine is for resistance welding and has a series of stationary angularly arranged electrodes. A second series of electrodes have a rolling movement with respect to a workpiece and they cooperate with the stationary electrodes to produce continuous, overlapping welds along adjacent, angularly disposed sides of the workpiece.

ANNUAL MEETING

American Welding Society
and
National Metal Congress
and Exposition
Chicago, Oct. 19-25.

AO Offers

Immediate Delivery on Welders' Gloves

Now ready again for immediate shipment—AO 5X143 Welders' Gloves—the gloves most welders want. Made of selected chrome-tanned cowhide leather. Gunn cut—one-piece back reduces number of seams to absolute minimum. Lined on back of hand from wrist to fingertips. Welted at all vulnerable seams for added strength. AO makes a correct type of glove or mitten for every industrial need. Send to your nearest AO Safety Representative for complete information.

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SECTION ACTIVITIES

BOSTON

The February meeting held at the Engineer's Club, on the 3rd, was in the form of a quiz program, or "Amateur Night." This program featured a quiz, covering the broad field of welding, with a board of "Experts" and awards for the highest scores. The board of judges consisted of W. L. Warner, Watertown Arsenal, L. W. Pote, C. P. C. Welding and Engineering Co. and F. L. Brandt, Thomson Electric Welder Co.

The after-dinner speaker at this meeting was John Nicol Mark, who gave a humerous talk under the title, "Scotch Wit with a Little Philosophy."

BRIDGEPORT

The Bridgeport Section held its first meeting of the season on November 14th, at the Oxy Acetylene Supply Co. showrooms in New Haven.

The main event of the evening was a demonstration of powder cutting of stainless steel by the A. B. King Co. of New Haven. A sound movie on stainless steel also was presented.

On December 5th, a joint meeting of The Engineers' Club of Bridgeport and the Bridgeport Section of the A.W.S. was held in the South Parlor of the Stratfield Hotel in Bridgeport.

A fine nontechnical discussion was presented by Albert D. Eplett, chief metallurgist of The Manning, Maxwell & Moore Co. of Bridgeport. The lecture entitled "A Peek from a Jeep in the E.T.O." concerned comparative production practices in America and Germany. An informal discussion between Mr. Eplett and the audience followed.

CINCINNATI

The regular meeting of this Section was held on January 28th. P. J. Patton of Ransome Machinery Co., Dunellen, N. J., spoke on the subject "Positioners for Welding." Mr. Patton's experience in all types of welding is very broad and he was therefore in a position to speak thoroughly the subject. A movie "New Horizons in Welding" was also shown.

CLEVELAND

E. A. Mallett, Sales Engineer of the Taylor-Winfield Corp., Warren, Ohio, spoke at the regular monthly meeting held on February 12th. Mr. Mallett discussed "Resistance Welding in Europe" and reviewed his observations of the plants and laboratories in England and Sweden during a ten-week tour of those countries during the latter part of 1946.

The fascinating new field of paper tape magnetic recording was the subject of the coffee talk given by F. "Chuck" Gilmour of the Brush Development Co. The "Soundmirror" paper tape magnetic system has been both a hobby and a vocation with Mr. Gilmour and has been under his jurisdiction at the Brush Development Co. for several years. Members were given the opportunity to have their voices recorded and played back at the meeting.

COLORADO

The first dinner meeting in some time was held on January 14th at the Auditorium Hotel, Denver, Colorado. R. S. Babcock, of The Linde Air Products Co., talked on "Plate Edge Preparation and Stack Cutting." A film on "Wrought Iron" was shown through the courtesy of the A. M. Byers Co. Both the film and Mr. Babcock's talk were of interest to all.

COLUMBUS

The Columbus Section reports the following activities for the past few months:

On November 8th, S. R. Dickerson, of Pullman Standard, presented a paper on "Fabrication of Steel Cars."

On December 13th, V. E. Wilson, of Haynes Stellite Co., spoke on "Hard Facing of Alloys in Industry Today."

On January 10th, Ira T. Hook, of the American Brass Co., Bridgeport, Conn., gave a talk on "Welding of Copper Alloys," and also presented a movie on copper mining.

A the February 21st meeting, G. O. Hoglund, chief engineer of the Aluminum Company of America, spoke on "Aluminum Welding."

On February 14th there was a joint meeting of the American Society for Metals and the Columbus Section of the A.W.S. The speaker was A. L. Gorman of the Allis-Chalmers Co. His subject was "Welded Electronics."

DETROIT

The opening meeting of the Affiliate Council Specialist Program was sponsored by the Detroit Section of the A.W.S. on January 21st.

J. R. Stitt, Research Engineer of the R. C. Mahon Co., discussed the topic "Effect of Temperature Gradients Upon the Introduction of Residual Stresses in Weldments."

A national authority on welding and stresses in weldments, Mr. Stitt was formerly Professor of Welding Engineering at Ohio State University, in fact the first to teach that subject at the institution.

INDIANA

The first 1947 meeting was held on January 24th at Buckley's, Cumberland, Indiana. J. A. Gallaher, district manager, Haynes Stellite Co., Chicago, presented the subject "Hard Surfacing of Parts."

A coffee talk on "Mushroom" and a very interesting sound film were also presented.

LEHIGH VALLEY

The Lehigh Valley Section held its monthly meeting on Monday, February 3rd, at the Hotel Bethlehem, Bethlehem, Pa. A sound film, "Everyday Miracles," showing cutting with carboloy tool steels was shown to the members and guests, following dinner.

Dr. Gilbert E. Doan, Chairman, presided at the technical meeting. Dr. Doan introduced the guest speaker, L. J. Cogan of the Graver Tank & Mfg. Co. Mr. Cogan spoke on "Inspection of Metal Arc Welds." He spoke of the requirements and duties of a welding inspector, methods of inspecting and testing welds, and the causes and cures of improperly made welds.

LONG BEACH

Meeting held on January 17th at the New Masonic Temple. Dinner preceding the meeting at Brittany Kitchen. J. P (Mike) Weed, of the North American Aviation Corp., spoke at the dinner and also at the technical meeting. Mr. Weed's dinner talk was on the advantages of a Section in Long Beach, Calif. His technical address was on "The Adoption of Arc Welding on Light Gage Aluminum in Aircraft." Mr. Weed's address took the listeners from the time of the adoption of the arc in aircraft to the welding and construction of the V-2 Rockets and the future of gas welding predominating in aircraft.

LOS ANGELES

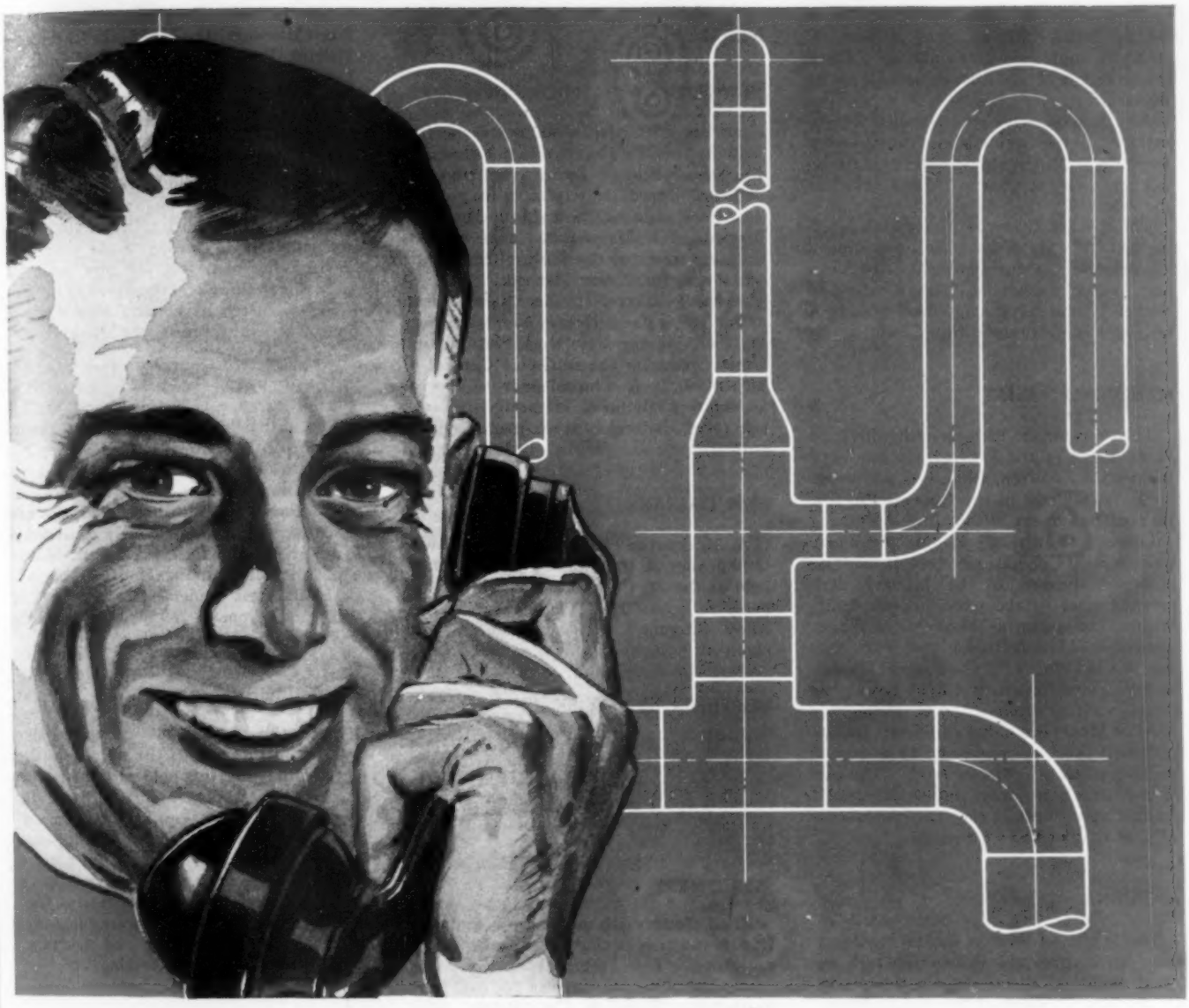
The February meeting held on the 21st was in the form of a plant visitation and dinner given to members only by the Consolidated Steel Corp. plant in Maywood. The Section is very much indebted to Al Fenlason and Lloyd Earl, vice-president of Consolidated Steel Corp, for making this dinner and plant visitation possible.

The April 17th meeting will also be a plant visitation graciously offered by the C. F. Braun Co., which was arranged through Charles Haynes, general plant superintendent for C. F. Braun. Mr. Haynes will be on hand to supervise the tour. The C. F. Braun Co. is located at 1000 South Fremont Ave., Alhambra, Calif.

LOUISVILLE

The January meeting of the Louisville Section was held in the Colonels Room of the Kentucky Hotel, January 28th.

The after dinner speaker was Earl Ruby, columnist and Sports Editor of the *Louisville Courier Journal*, who spoke on "The Sport's Parade."



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ONE SOURCE OF SUPPLY FOR ALL WELDING FITTING REQUIREMENTS

After a short recess Mario Sciaky of Sciaky Bros., Chicago, gave a most instructive and enjoyable talk on "Three Phase Balanced Load Resistance Welding Machines."

Mr. Sciaky, who was engaged in the manufacture of welders in France before World War II, gave some interesting sidelights on his experiences before and after the war.

The speaker at the February 25th meeting was R. M. Wilson, Jr., mechanical engineer for the International Nickel Co. Mr. Wilson spoke on "The Welding of Nickel, Nickel Alloy and Monel Metal for Low and High Temperature Service."

MAHONING VALLEY

The November 12th meeting held at Plant No. 4 of the Federal Machine and Welder Co., Warren, Ohio, was addressed by R. T. Gillette of the General Electric Co., on the subject "Resistance Welding."

Leonard Williams, welding engineer, Lukens Steel Co., Coatesville, Pa., was the principal speaker at the January 21st meeting held in the Ohio Edison Auditorium, Youngstown, Ohio. Mr. Williams discussed "Manufacturing and Fabricating of Clad Steels." Clad steels are bimetalic plates in which a light layer of a metal, such as stainless steel, nickel, inconel or Monel is bonded uniformly, homogeneously and permanently to a heavy backing plate of ordinary steel. The use of clad steels in many industrial applications may effect savings in cost up to 60% of that of the solid metal.

MICHIANA

The Michiana Section was treated to a most interesting and instructive talk on "Arc Welding Electrode Coatings" by Dr. DeWitt C. Smith of the Harnischfeger Corp., Milwaukee. Dr. Smith gave a brief history of the development of coated electrodes, then he described the coatings used on the E6010, E6011, E6012, E6013, E6020 and E6030 types and discussed the type of bead laid by each and how and where it should be used. He closed by describing the new lime-ferritic electrode developed during the war and suggested many possibilities for its use in peacetime manufacturing.

MILWAUKEE

The regular monthly meeting of the Milwaukee Section was held on Friday, January 24th, at the Ambassador Hotel.

The after dinner program consisted of a color movie "The Plywood Fleet," showing a scenic trip down the Canyon of the Colorado.

The main speaker of the evening was Patrick S. Doyen, field engineer, Welding Equipment and Supply Co., Detroit. Mr. Doyen's subject "Tool and Die Welding" is one in which he is well versed in the theoretical and practical side. He has lectured and conducted classes in this type of welding in the technical and trade schools in Detroit, Mich.

Two slides of sound films, "Let's Get the Low-Down," and "Let's Do It Right," were shown.

NEW JERSEY

At an Executive Committee meeting held on January 21st, it was reported that the Forum held on January 6th was well attended, approximately 150 were present. The last forum will be held on April 7th. Mr. Migel of Magnaflux Corp., will address the forum on the subject "Magnaflux and Zyglo Inspection Methods."

At the January 21st dinner meeting held at the Hotel Essex House, Newark, Harry W. Pierce of the New York Shipbuilding Corp., spoke on the subject, "Control of Distortion." A comprehensive review of all known methods of preventing the effects of distortion were made by the author.

NEW ORLEANS

A. M. Setapen of Handy & Harman was the speaker at the January 10th meeting held at the St. Charles Hotel. Mr. Setapen's talk on "Low Temperature Silver Alloy Brazing," was exceptionally well received.

NORTHERN NEW YORK

L. M. Benkert, of Progressive Welder Co., will speak on "Resistance Welding" at the March 27th meeting.

The Annual Meeting of the Section will be held on April 24th.

NORTHWEST

The February 5th meeting was a double feature meeting in that two speakers were scheduled. The technical speaker was James W. Owens, director of welding, Fairbanks, Morse & Co., Beloit, Wis. Mr. Owens' subject was "Welding and Flame Cutting." Mr. Owens is in charge of the welding department of the new 15 million dollar weldry of Fairbanks, Morse & Co., which has achieved some remarkable improvements in weldments. Mr. Owens discussed some of the important work they have been doing.

The second speaker at the meeting was George N. Sieger, president of S-M-S Corp., Detroit, and second vice-president of the A.W.S. Mr. Sieger spoke on the "Scope and Activities of the Society."

NORTHWESTERN PENNSYLVANIA

The regular monthly meeting was held on January 30th, at the G. E. Community Center, Erie, Pa. R. F. Helmkamp of the Air Reduction Sales Co., spoke on the "Use of Oxy-Acetylene for Metal Fabrication."

PEORIA

On Wednesday, January 22nd, the Peoria Section held their annual business meeting in the Jefferson Hotel. After dinner, results of the election of officers for the ensuing year were given and the new officers introduced as follows: Chairman, K. H. Jackson, Caterpillar Tractor Co.; Vice-Chairman, G. W. Plank, Caterpillar Tractor Co.; Secretary, Lyle Bibb, R. G. LeTourneau Co.; Treasurer, John Hanley, J. Lucas & Son; Executive Committee, H. E. Baldwin, Clifford Wimmer, and D. E. McCowan; Directors, Larry O'Day, Edwin Schmidt, and George Deemey.

After the introduction of the above officers, the retiring Chairman and Chairman-elect made short talks to the group reviewing the activities of the past year and making plans for the new year. A discussion followed on the topics of interest to be discussed at coming meetings. A film of general interest was also shown.

PHILADELPHIA

The Fifth Panel Discussion Group Meeting of the 1946–47 season was held on Friday, February 7th, in the Engineers' Club Junior Room. Subject of discussion was "Resistance Welding Electrodes and Fixtures." Panel of speakers consisted of William R. Crawford, ACF-Brill Motors Co., John MacKinney, The Budd Co. and C. H. Benker, General Electric Co. K. William Ostrom of K. W. Ostrom & Co. was director of the meeting.

PITTSBURGH

R. W. Emerson of the Pittsburgh Piping & Equipment Co. was the dinner speaker at the dinner meeting held on January 15th at the Hotel Webster Hall. Mr. Emerson's talk on "Post War Trip to Germany" was very interesting. The technical meeting was held at the Mellon Institute of Industrial Research. H. O. Klinke of the Air Reduction Sales Co., Jersey City, N. J., spoke on "New Developments of Inert Gas Arc Welding and Cutting," which was also very interesting.

PUGET SOUND

President L. W. Delhi was the speaker at the January 21st meeting. Mr. Delhi explained the structure of the Society with its Sections and divisions. The drives for increased membership by various sections and the success which they have had was discussed. Mr. Delhi closed his remarks by mentioning the Western Metals Congress to be held in Oakland, Calif., March 22nd to 27th.

Two colored movies, one by the Lincoln Electric Co., called "Design for Arc Welded Structures," and the other on "Your City Light" were shown. The latter film portrayed the beauties of the Skagit River Country with all its wild life and mountain scenery.

At the February 18th meeting, R. F. Wyer, in charge of welding applications engineering, General Electric Co., Schenectady, spoke on the subject "The Welding Arc in Hydrogen, Helium and Argon."

ROCHESTER

The regular monthly meeting of the Rochester Section was held on February 6th, at the University of Rochester. Dinner preceded the meeting at the Centry Sweet Shoppe. John K. Light, district

manager, Arcos Corp., Hartford, Conn., and James E. Norcross, sales manager, of the same company, presented some new information on the subject "Welding of Stainless Steel." A motion picture on the subject was also shown.

SAN FRANCISCO

The January meeting was held at the Engineers' Club on the 27th. The meeting was addressed by Russell G. Rhodes, welding engineer, Bechtel Corp., of San Francisco, who offered a paper entitled "Radiography as a Control for Welding Joints in Pipe Lines." Mr. Rhodes' very interesting talk was accompanied by slides and graphs which illustrated his point excellently.

After the technical session, the new General Electric technicolor sound film, produced in cooperation with RWMA, entitled "This Is Resistance Welding," was presented. A. D. Boardman, of General Electric, and Mr. Ward Schaffer, of the Pacific Gas & Electric Co., were on hand to answer questions relative to controls and power in resistance welding.

WASHINGTON

At a joint special meeting of the Washington Section of the A.W.S., A.I.E.E., A.S.M.E., A.S.C.E., A.S.H.V.E., A.S.M., I.R.E., A.S.P.E., A.I.S.M., D.C.S.E., held on January 14th, the Washington Section was honored in sponsoring the appearance of Dr. Vannevar Bush, in cooperation with other local engineering society sections. This is the second annual meeting so sponsored, Dr. Charles Kettering having been presented last year. It is the hope of the Section to continue the practice of presenting outstanding national figures at future annual meetings.

About 1400 persons packed the Interior Department Auditorium to hear Dr. Bush, chairman of the Joint Research and Development Board, outline a plan for putting Government support of scientific research on a firm and permanent basis. Dr. Bush urged that the new Congress create a National Research Foundation under civilian control. Dr. Bush is one of the Nation's leaders in atomic development. Dr. Bush emphasized the largeness of responsibility for scientific development.

The regular January meeting was held on the 28th at the Potomac Electric Auditorium, with Arthur J. Raymo, Baldwin Locomotive Works, as the speaker. Mr. Raymo discussed "The Use of Welding Processes in Railway Motive Power Equipment." The talk covered the history of the steam locomotive and continued into the history of the Diesel electric locomotive, which was almost completely welded from birth and has been accepted by industry. An extremely interesting group of slides illustrated the talk.

WESTERN MICHIGAN

The regular monthly meeting was held on January 20th. G. O. Hoglund, welding engineer, Aluminum Company of America, New Kensington, Pa., spoke on the subject "Welding and Brazing Aluminum," which was illustrated with slides and motion pictures. Mr. Hoglund discussed all phases of arc, gas and resistance welding, as well as gas shielded arc welding, considering the relation of these processes to the welding and brazing of aluminum. His talk covered many of the new applications of inert gas shielded arc welding of aluminum sheet and extruded shapes.

WORCESTER

The February 4th meeting was held at Howard Johnson's Restaurant, Shrewsbury, Mass. Arthur M. Unger, welding engineer, Pullman Standard Car Mfg. Co., Chicago, was the speaker of the evening. His topic was "Quantity Production by Welding of Railroad Passenger Cars." Mr. Unger's talk described large automatic welding equipment installed for various subassemblies of the car structure. Color slides showed the progress made by welding over a number of years on railroad equipment.

YORK-CENTRAL PENNSYLVANIA

The regular monthly meeting was held on February 5th in the Engineering Building, York, Pa. Dinner at the Yorktowne Coffee Shop preceded the meeting. A lecture and demonstration on "Silver Brazing" was presented by A. M. Setapen, manager, Engineering Division, Handy & Harman.

Annual banquet and dance will be held on April 16th at the Out Door Club, at 7 P.M.

Dinner meeting of the Toronto Chapter was held on February 3rd at Malloneys Art Gallery. "Thermit Welding" was presented by John B. Tinnon, vice-president of the Metal and Thermit Corp., New York City.

CANADIAN

The fifth meeting of the 1946–47 series of the Hamilton Chapter was held on February 4th at McMaster University. "Welding and Its Relationship to the Canadian Standards Bureau" was presented by W. R. Stickney, welding engineer, Canadian Welding Bureau.

List of New Members

January 1 to January 31, 1947

BIRMINGHAM

Braswell, S. F. (B), 109 72nd St. No., Birmingham 6, Ala.
Davis, E. A. (B), Box 277, Birmingham 1, Ala.
Stiles, Lloyd C. (B), 3017 Highland Ave., Birmingham, Ala.
Williams, Bart D. (C), P. O. Box 277, Birmingham, Ala.

BOSTON

Freedman, George (C), Raytheon Mfg. Co., 55 Chapel. St., Newton, Mass.
Schlenker, Rudolf P. (B), N. E. Trawler Equip. Co., Eastern Ave., Chelsea, Mass.
Spear, Robert E. (C), 119 Park Ave. West, South Weymouth, Mass.
Welshman, Hugh, Jr. (B), Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.

BRIDGEPORT

Del Vecchio, Carl J. (C), 35 Puritan Lane, Stamford, Conn.

CANADA

Chatfield, H. W. (B), Angus Shops, Rachel St., Montreal, P. Q., Canada.
Davies, Norman H. (C), Canadian Sirocco Co., 310 Ellis Ave., Windsor, Ont.
Layt, George H. G. (C), 2880 Van Horne Ave., Montreal, Canada.
MacDonnell, Angus (C), Canadian Sirocco Co., 310 Ellis Ave., Windsor, Ont., Canada.
St. Denis, Stuart (B), 318 A King St., Welland, Ont., Canada.

CHICAGO

Airdo, James (B), Notre Dame Pharmacy, 1361 W. Harrison St., Chicago 7, Ill.
Clarke, Harry J. (B), Chicago Bridge & Iron Co., 1305 W. 105th St., Chicago 43, Ill.
Katone, Frank (C), The Superheater Co., 151st and Railroad Ave., East Chicago, Ind.

(*Continued on page 290*)

Heliarc

Another Linde high-speed welding method

Production of 300 Aluminum Rocket Motor Cases Daily

Mechanized speeds of 14 in. per min. were established in HELIARC welding rocket cases of 0.0625-in. to 0.125-in. 3S aluminum.

Large Savings in Welding Aluminum Fruit Ship Ventilators

A shipbuilder found that by replacing metallic arc welding with HELIARC welding, he could reduce warping and cleaning, reduce overall welding time approximately 40 per cent. The ventilators were fabricated of 52 S-H, ¼-in. aluminum.

Increased Life of Silver Coils Worth $70,000

The high quality of the butt and fillet welds made in 0.065-in. silver coils with the HELIARC process extended their normal service life considerably.

Production of Stainless Steel Plates Increased Four-Fold

Hand-welding these heat exchanger plates of Type 302 stainless steel with the HELIARC process reduced cleanup time, decreased the number of "leakers," and increased production 300 per cent.

Production of Four Magnesium Seat End Frames Hourly Per Man

Typical of the many magnesium welding operations is the fabrication of aircraft seat end frames, made from six magnesium tubular parts. Complete operation of jigging and making all 32 welds in the structure by HELIARC welding required about 15 minutes.

Only Possible Process for Aircraft Magnesium Castings

HELIARC welding for hand-welding butt, lap, and fillet joints in small magnesium castings made possible the production of certain vital parts for aircraft radar equipment.

$8,000 Savings in 33,000 Stainless Steel Stove Parts

With the mechanized arrangement for making butt welds in 0.035-in. Type 306 stainless steel by the HELIARC process, a welding speed of 40 in. per min. was obtained. Units were welded at an average of 40 per hour, and savings of 27 per cent over the former method of production were realized on one order of 33,000 units.

CLEAN, SMOOTH JOINTS IN METALS THAT ARE DIFFICULT TO WELD BY OTHER METHODS

Linde's HELIARC process is a method of arc-welding in which the welding action is shielded by an inert gas—usually argon.

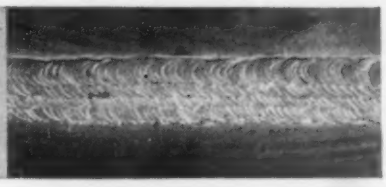
Joints welded by the HELIARC process have exceptionally high quality. They are clean, because HELIARC welding eliminates flux. Joints are so smooth, even, and neat that usually no finishing treatment of any kind is required.

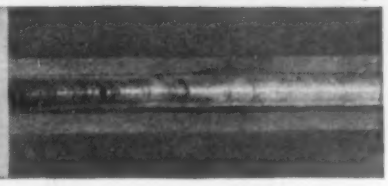
Linde service engineers are always available to help with problems of treating, cutting, joining and forming metals.

Call or write any Linde office for more information.

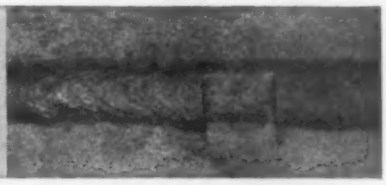
TYPICAL HELIARC WELDS

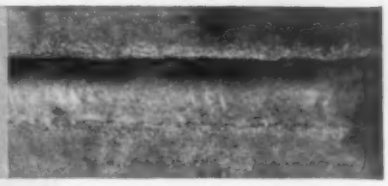
Aluminum 3S—0.5 in. thick, 2 passes at 10 in. per min. per pass.

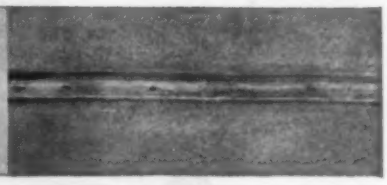

Aluminum 3S—2.5 in. thick, 32 passes at 4.2 in. per min. per pass.

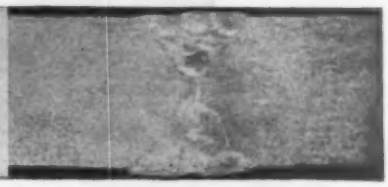

Aluminum 2SO—0.125 in. thick, 22 in. per min.

HASTELLOY, Alloy B—0.050 in. thick, 24 in. per min.


Cast Iron—0.375 in. thick, 8 in. per min.


Magnesium—0.5 in. thick, 2 passes at 8 in. per min. per pass.


Stainless Steel, type 304—0.062 in. thick 24 in. per min.


Aluminum 3S—1.25 in. thick, 10 passes at 12 in. per min. per pass.

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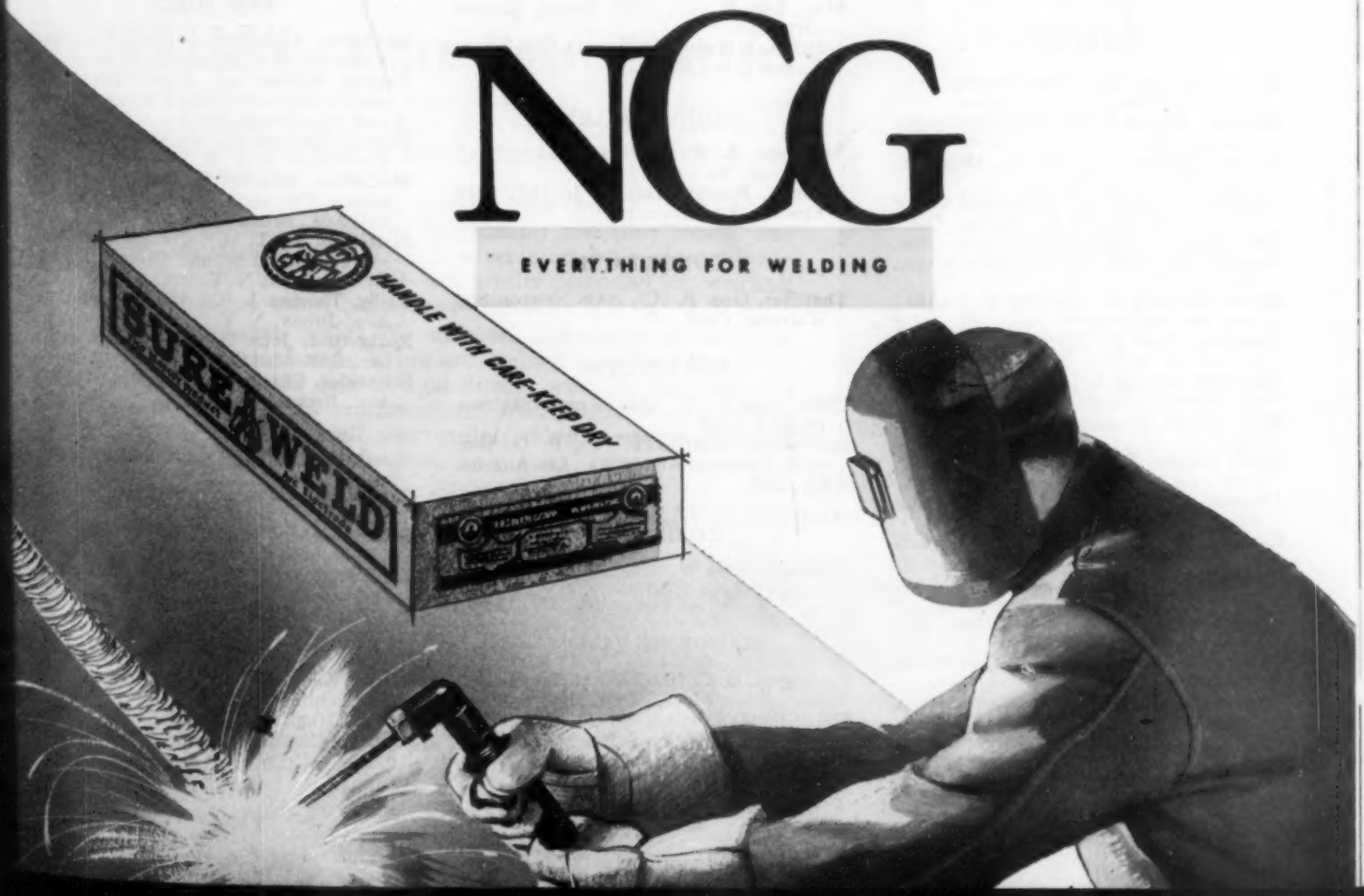

(*Continued from page 285*)

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Romann, John H. (B), U. S. Engrg. & Mfg. Co., 188 West Randolph St., Chicago 1, Ill.
Thichava, Edward J., Jr. (B), International Harvester Co., Melrose Park, Ill.

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Ruehl, William F. (C), 915 N. Augusta Ave., Baltimore 29, Md.

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Pytynia, Louis (B), 320 Madison St., Michigan City, Ind.

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Schneller, A. R. (C), 1823 N. 55th St., Milwaukee, Wis.
Webb, Arthur B. (B), 1021 E. Hampton Rd. 1, Milwaukee 11, Wis.

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Data on welding low-alloy, high-tensile steels is available without obligation. Write today.

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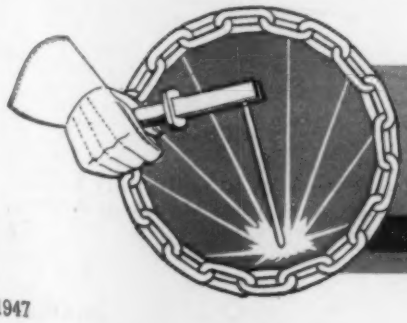

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Johnson, Calvin W. (C), 167 Parkway Dr., Syracuse 7, N. Y.
Kagi, Albert (C), 206 Briarcliffe Rd., R. D. 3, East Syracuse, N. Y.
La Barge, Charles B. (C), 421 Seneca Dr., Syracuse 5, N. Y.
La Graffe, Bernard (C), 1411 Spring St., Syracuse, N. Y.
Manning, Mark (C), 203 Harriette Ave., Syracuse, N. Y.
Mitchell, Arthur (C), San-Equipment Co., East Brighton and Glen Aves., Syracuse 5, N. Y.
Piazza, John J. (C), 414 Fabius St., Syracuse, N. Y.
Strauss, Raymond (C), R. F. D. 2, Manlius, N. Y.
Sykes, Ben (C), 121 E. Newell St., Syracuse 5, N. Y.
Teska, Edward J. (C), 106 Pond St., Syracuse, N. Y.

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Marzke, Oscar T. (C), Naval Research Lab., Washington 20, D. C.
Watts, William J. (C), R. D. 1, Box 58, Laurel, Md.

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Rinkeviczie, Clark (C), R. 1, Belmont, Mich.
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Aronson, Charles N. (B), Aronson Machine Co., Arcade, N. Y.

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Çourndyer, Bernard T. (C), 697 Burncoat St., Worcester 6, Mass.
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Wayne, Richard J. (C to B), 17008 Eldamene, Cleveland, Ohio.

MICHIANA

Perry, Peter M. (C to B), Perry Welding Sales & Service, Monroe at Fellows, South Bend 4, Ind.